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Original Communications

THE EFFECT OF PREOPERATIVE STREPTOMYCIN ON THE INCIDENCE OF BRONCHOPLEURAL FISTULA AFTER PULMONARY EXCISION FOR TUBERCULOSIS

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THE aim of this communication is to show that after pulmonary excision for tuberculosis, tuberculous lesions remaining in the bronchial stump contribute to the development of bronchopleural fistula and that streptomycin, by controlling this infection *before* operation, reduces the incidence of this formidable postoperative complication.

In order to assess the influence of bronchial disease on the complications following pulmonary excision, it is necessary to eliminate other factors which may affect the incidence of these complications. Because thoracoplasty, phrenic interruption and pneumoperitoneum may help to prevent bronchopleural fistula, empyema and reactivation of residual tuberculosis, no patient was included in this study who had any of these operations performed before, at the time of or after pulmonary excision. In all cases an essentially similar operative technique was used. Some patients were not given streptomycin before operation but all patients received streptomycin for at least four weeks after the excision. One gram of streptomycin was given daily. All patients were observed for at least three months after operation; the average period of observation was nine months.

The relationship between postoperative complications and the site of bronchial division was studied in 140 patients. It was found that there was no significant difference in the two sides but the incidence of complications did vary with the part of the lung removed. Table I shows that after excision of the lung or all or part of the upper lobe fistula, empyema and spread of disease [illegible] but after removal of all or part of the middle or lower lobe neither [illegible] empyema developed although some spreads occurred. However, [illegible] empyema developing fistula its incidence did not vary significantly with [illegible]

[illegible]
[illegible] Great Britain and Ireland, Liverpool

Since fistula did not develop unless all or part of the upper lobe was removed, the effect of preoperative streptomycin on the incidence of fistula was observed after excision of lungs and all or part of the upper lobes only. Thirty-three pneumonectomies, forty-six upper lobectomies, and twenty-eight upper segmental excisions were performed on 107 patients. Of these patients thirty-five had para-aminosalicylic acid with the streptomycin and seventeen had received streptomycin previously but more than six months before operation. In Table II the patients are grouped according to whether they received preoperative streptomycin or not. In the group which did not receive streptomycin before operation 50 per cent developed fistulas. Whereas in the group which received streptomycin in the immediate preoperative period 16 per cent developed fistulas.

TABLE II. EFFECT OF PREOPERATIVE STREPTOMYCIN TREATMENT ON INCIDENCE OF FISTULAS

	TOTAL	WITH FISTULAS
Patients not receiving streptomycin within 6 months of operation	28	14 (50%)
Patients receiving streptomycin within 6 months of operation	79	[illegible] (16%)

The central end of the divided bronchus was examined for evidence of tuberculosis in thirty-one operation specimens: seventeen lungs, ten lobes, and four segments excised for this disease. Bronchi considered to be tuberculous showed typical tubercles of lymphocytes, epithelioid cells, and multinucleated giant cells. In some tubercles there was caseation. Although they occasionally extended more deeply, the lesions were found always in the submucosa. In some cases the overlying epithelium was intact; in others it was ulcerated by the subepithelial infection. The tuberculous lesions were found in twenty-seven of the thirty-one bronchi examined. The [illegible] Tuberculosis Association reported the [illegible] [illegible] tuberculosis was found [illegible] in 95 per cent. The 87 per cent [illegible] present [illegible] Table III.

TABLE III. [illegible]

the bronchial stumps left in the patients. In two patients who had upper lobectomies no evidence of tuberculosis was found in the divided bronchi of the operation specimens. Both patients developed bronchopleural fistulas after operation. After completion pleuropneumonectomy in one and at necropsy in the other tuberculous lesions were found in the bronchi at the site of the fistulas.

Tuberculous infection of the bronchial stump might cause the disease to spread to residual lung tissue or the pleural cavity. It is likely also to interfere with healing of the divided bronchus and lead to the development of a bronchopleural fistula. Thus it seems reasonable to suppose that the reduced incidence of fistula shown in Table II was due to suppression of bronchial infection by the preoperative streptomycin. Furthermore, Table IV shows that the incidence of fistula is influenced by the duration of streptomycin treatment before operation. In the group of twenty-eight patients who did not receive the benefit of streptomycin given in the immediate preoperative period one-half developed fistulas. When streptomycin was given to forty-five patients for three weeks or less before operation the incidence of fistula was reduced to one-fourth; of thirty-four patients in whom streptomycin treatment was maintained for more than three weeks only two developed fistulas.

TABLE IV. INFLUENCE OF DURATION OF PREOPERATIVE STREPTOMYCIN TREATMENT ON INCIDENCE OF FISTULA

PREOPERATIVE STREPTOMYCIN	TOTAL NO. OF PATIENTS	WITH FISTULAS
None	28	14 (50%)
3 weeks or less	45	11 (24%)
More than 3 weeks	34	2 (6%)

SUMMARY

Tuberculous lesions are very common in bronchial stumps and probably are an important factor in the development of bronchopleural fistula. This view is supported by the finding that preoperative streptomycin treatment reduced the incidence of fistula after excision of the lung or all or part of the upper lobe. It is evident also that the patient may not be protected adequately by streptomycin given for a short period before operation and it is advocated that pulmonary excision for tuberculosis be preceded by streptomycin treatment for at least three weeks.

[illegible] included in this study with the kind permission of several physicians and [illegible] St. George's Hospital, London, Poole Hospital, Middlesbrough, Milford Chest [illegible] Hospital, London, and King George V Hospital for Diseases [illegible]

REFERENCE

[illegible] British Tuberculosis Association Research Committee on "Tuberculous [illegible] Thorax [illegible] 31 [illegible] 1953

SIMULTANEOUS OCCURRENCE OF SIMPLE AND MALIGNANT TUMORS IN THE ESOPHAGUS

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CARCINOMA of the esophagus is a common cause of dysphagia in older people. Simple tumors of the esophagus are less often responsible, and of these leiomyoma is probably the most frequent type. There has been a renewed interest in nonmalignant conditions causing obstruction in the last few years (Moersch and Harrington,[1] Calmenson and Clagett,[2] Myers and Bradshaw[3]), but a search of the literature does not reveal any case where the two conditions occur simultaneously in the same patient. The case report presented appears to be unique in this respect.

Operation—Esophagectomy (Mr D Barlow, Dr Leighton), a two stage operation, was performed at one session

1 *Abdominal part* A left upper paramedian incision was made Findings No obvious malignant spread, although the glands in the lesser omentum toward the cardia were freely palpable and firmer than normal Specimen was sent for section (the report of which showed no involvement by growth) The stomach was mobilized from the duodenum to the lower end of the esophagus The abdomen was closed and the patient was turned onto the right side

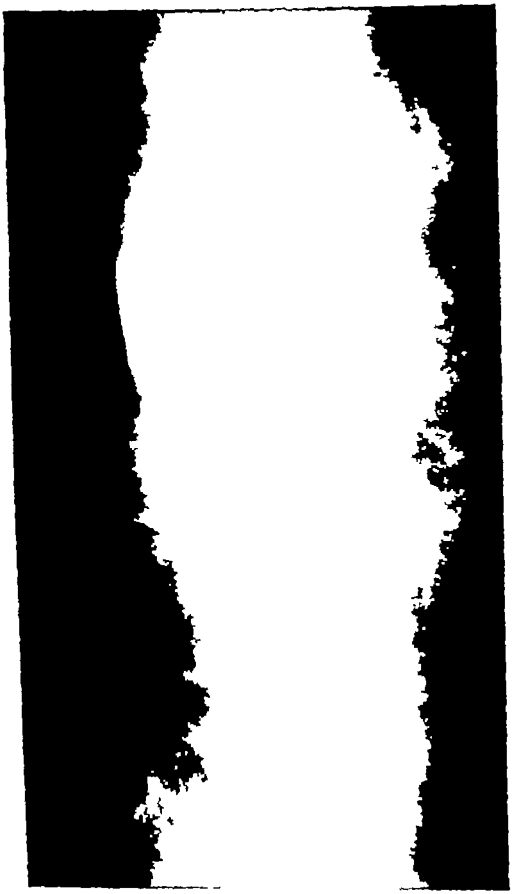

Fig. 1 [illegible] barium swallow There is a short stenosis with dilatation visible above it On [illegible] a smooth rounded projection 1 [illegible] cm in length is present below the

2 *Thoracic part* [illegible] This was done through the bed of the seventh rib which was [illegible] A malignant stricture of the esophagus with secondary malignant nodules [illegible] in the region of the thoracic [illegible] adherent to both trachea and esophagus Proce[illegible] [illegible] the growth was removed after mobilization of the esophagus [illegible] The [illegible] end of the stomach was closed and invaginated End to side ana[illegible] [illegible] The level of the transection of the esophagus was 1½ inches [illegible] [illegible] rib The chest was closed with drainage over penicillin tablets

[illegible] swallowing soft foods without difficulty or discomfort until [illegible] On examination [illegible] coarse rhonchi [illegible] X-ray [illegible] air and fluid in the pleural

[illegible] from the

DISCUSSION

The etiology of both leiomyoma and carcinoma of the esophagus is largely unknown The smooth muscle tumors are assumed to be congenital in origin, and some previously reported cases support this view For example, Rose's case, where multiple leiomyomas occurred in the esophagus and stomach, could be interpreted as illustrating an anomaly confined to the primitive foregut In the myometrium, leiomyomas are common, and they can be produced experimentally by the use of estrogen Rhythmical hormonal variation in concentration is believed to be the cause of the condition in human beings also, but there is no evidence to suggest that the esophagus is subjected to such humoral influences Two of the factors thought to be predisposing causes in the pathogenesis of carcinoma of the esophagus, discussed by Wu and Loucks,[7] are illustrated in this case, namely (1) a long period of consumption of hot liquids and foods and (2) a family history of cancer

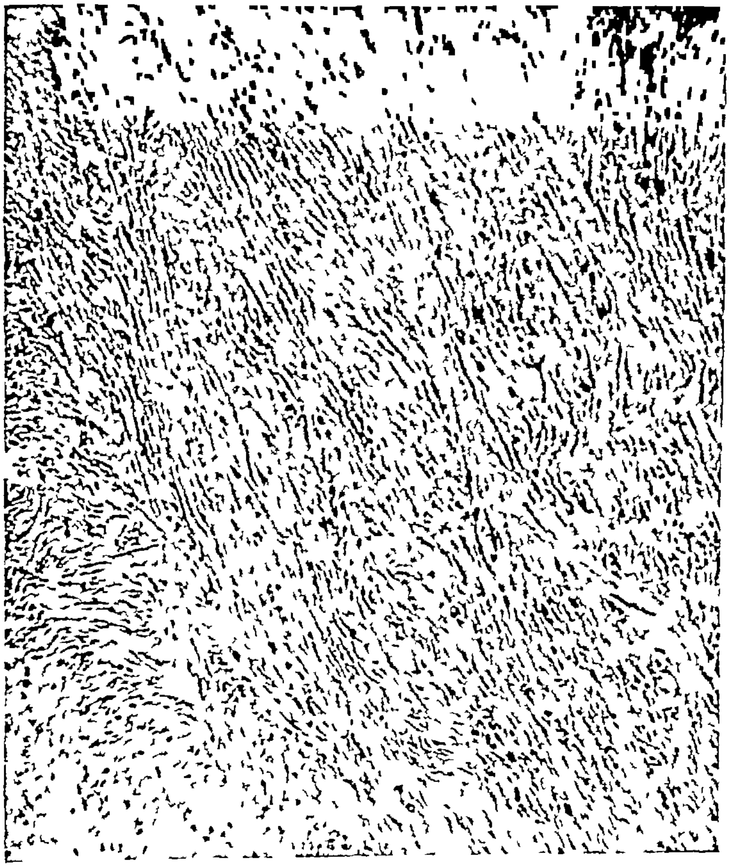

Fig 4 — High-power view of leiomyoma (X200)

The duration of symptoms before the patient presented himself is one year This is longer than the average in reported series of cases of carcinoma of the

[illegible] High [illegible] of carcinoma (× 200)

[illegible] In Franklin and Shipman's series of 159 cases 60 per cent had [illegible] or three months or less and only six patients had symptoms for a [illegible]

[illegible] the smooth muscle tumor must have played [illegible] In the [illegible] segment of the esophagus the diameter of the leiomyoma was 0 58 cm The average width of the esophageal wall in these sections is 0 9 cm, so that at that level nearly 60 per cent of the thickness of the wall was due to the tumor As sections from different parts of the block show the simple tumor to extend at least some distance around the circumference of the esophagus, encroachment on the lumen must have been present The narrowing so produced was further accentuated by the superimposition of a carcinoma here Fig 2 shows these points clearly In the barium swallow (Fig 1), below the narrowed area, is a rounded shadow on the right, 1 25 cm long, which could be a mucosal projection due to the underlying leiomyoma Such an appearance is not characteristic of a malignant obstruction It is recognized that points of constriction in the esophagus are more frequently the sites of carcinoma than are the intervening areas, according to Aird,[1] and it could, therefore, be argued that by accenuating this anatomical feature in a subject predisposed to carcinoma for other reasons, the simple tumor indirectly aided the development of the malignant one

Previous investigators, including Rose,[6] held the opinion that solitary myomas are incidental findings and do not produce symptoms unless they are at least several centimeters in size Yet, if a solitary tumor began to increase in size, it could produce the sequence of events described In this instance, there is no evidence either way to form a firm opinion about the behavior of the myoma On clinical grounds, the total length of symptoms is a feature suggesting that the leiomyoma was at first responsible for his symptoms, perhaps through recent growth in a concentric direction

SUMMARY

1 A case of the simultaneous occurrence of squamous carcinoma and adjacent leiomyoma of the esophagus is described

2 The relationship between the clinical picture and the pathology found is discussed

This case was under the care of Mr Donald Barlow, M S, F R C S, to whom I am indebted for permission to publish it

Dr K W F Hinson did the pathological examinations and reported on the specimen My thanks are also due to Mr J M. Webster for the photomicrographs

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CHYLOTHORAX FOLLOWING A BLOW TO THE ABDOMEN

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According to Zesas[1] the first description of a case of traumatic chylothorax was made by Bartolet in 1633. In 1946, Lampson[2] demonstrated that the condition could be cured by ligation of the thoracic duct in the lower chest. In 1938, Shackelford and Fisher[3] reported forty-one cases of traumatic chylothorax found in the literature, while Lampson found eighteen additional cases. Baldridge and Lewis[4] divided the cases into the following categories. Cases due to operative trauma were not included in Shackelford's series.

	SHACKELFORD AND FISHER 1938	LAMPSON 1947
Crushing injuries	17	1
Wounds (bullet and stab)	8	5
Fall from height	6	2
Blow on chest	5	2
Thrown against seat of automobile	4	--
Hyperextension	1	--
Auto accident with collision	--	2
Hit by automobile	--	1
Severe coughing	--	1
Surgical accident	--	4
	41	18

It is interesting to note that Shackelford and Fisher stated in 1938 that "surgical ligation of the duct is physiologically compatible with life, but clinically impractical at present." Since Peet and Campbell[5] reported the first successful ligation of the thoracic duct and Lampson reported the second successful ligation, a number have been done including our presented case which showed that ligation is clinically practical.

Traumatic chylothorax in children seems to occur rather frequently. Janet, Boegner and Laquerriere[6] quote Kirchner, who reported the case of a child of 9 years of age who was pushed against a window bar by another child and fifteen days later developed a chylothorax. They also quote a case reported by Muttermilch of a 5 month-old infant who was dropped out of bed by its mother and in falling knocked against its cradle. It was apparently normal for two to three weeks and was then found to have a chylothorax. Sakula[7] in 1949, stated that chylothorax in infancy is an extremely rare condition and a search of the literature revealed thirteen cases under the age of 1 year, five of which occurred in the first four weeks of life. Sakula added another case in an neonate. In early infancy, usually designated as spontaneous after this age practically all cases of chylothorax are associated with injury.

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CASE REPORT

S C a boy, aged 7 years, presented himself with symptoms of shortness of breath especially upon exertion. The only clue was given by the patient who stated that three weeks previously he was hit in the ' stomach by a younger cousin and shortly after that became short of breath. Examination by palpation revealed nothing abnormal in the abdomen where the child seemed to center his attention, especially over and near the spleen However, inspection of the chest revealed shallow respiration with some distention of the right side Auscultation revealed normal breath sounds in the left lung but no breath sounds were heard on the entire right side. Percussion revealed dullness over the entire right chest Fluoroscopically the left side was normal but the right side showed one solid shadow with no air visible Pulse and temperature were normal, the patient weighed 56¼ pounds He was admitted to St Elizabeth Hospital

An x ray film taken of the chest on admission was read as follows Films of the chest showed a rather massive effusion in the right pleural space which almost completely obscured the right lung There was moderate displacement of the mediastinal structures to the left Throughout the left lung fields there were multiple small rounded calcifications probably residual from tuberculosis or histoplasmosis In view of these findings in the left lung it was possible that the effusion on the right side was tuberculous

The same afternoon, July 29 1953, under local anesthesia 40 ounces of creamy fluid were removed from the right pleural cavity The distention of the right chest seemed to be greatly diminished The laboratory report of the fluid examination was as follows Smear showed no organisms There was no growth on culture Total protein 15 Gm. per liter, sugar 93 mg per cent, amylase 32 units, lipase 55 units, sp gr 1 012, total cholesterol 125 mg per cent Blood study showed the following Hemoglobin, 12.5 Gm., red blood count, 4,230,000 white blood count 10 800 polymorphs 58 lymphocytes 40 monocytes 2

Films made of the chest the next day revealed that recheck following the thoracentesis showed a considerable decrease in the amount of the effusion in the right pleural space There was, however, still considerable fluid remaining the fluid extended up to the level of the fourth rib in the midaxillary line Some air had been introduced into the pleural space and there was approximately 15 per cent collapse of the right upper lobe The right upper lobe was not well visualized and showed diffuse miliary like calcifications that were described in the left lung on previous study The mediastinal structures were now close to the midline Since the aspirated fluid was milky and since there was a history of previous trauma it was possible that the fluid accumulation could be chylous

Clinically it could be determined that fluid was accumulating A chest roentgenogram taken Aug 5, 1953, revealed the left lung remained unchanged and a marked increase in the amount of fluid in the right pleural space That same day the patient was tapped and 1 100 c c. of milky fluid were obtained. Despite the fact that no more fluid could be obtained at the level of the seventh interspace posteriorly films the next day showed very little change During the stay in the hospital the patient s temperature remained close to normal while the respiration varied between 20 and 36 Due to administrative and financial difficulties he was dismissed from the hospital pending arrangements for future surgery

He was readmitted on Aug 17 1953 and on that same day 1 400 c c of cream colored fluid were withdrawn. On Aug 21 1953 1 700 c.c. were withdrawn on Aug 26, 1953, 1 800 c.c was withdrawn. An x ray film made on Aug 28 1953 showed that the left lung remained clear while there appeared to be a slight decrease in the amount of fluid on the right On Aug 30 1953 2 000 c.c. of fluid were withdrawn and on Sept 3 1953, 1,200 c.c. were withdrawn. Recheck films made on Sept 4 1953 showed no apparent decrease in the amount of effusion since the previous x ray study There appeared to be some loculation of the fluid which was not evident on previous studies There was still some displacement of the mediastinal structures During this period the repeated aspirations kept the patient comfortable but did not succeed in keeping him dry

On Sept. 5, 1953, the patient was operated on (M. R) With the patient under satisfactory general anesthetic (Pentothal Sodium and nitrous oxide and ether), he was placed in position for a right thoracotomy The right pleural space was entered through the eighth intercostal space Upon opening this, approximately 1500 c c of chyle were removed by suction The lung itself was markedly compressed However, there were very few adhesions present and the pleural surfaces were glistening The lung was reflected anteriorly and the posterior aspect in the region of the spine was examined On the anterior surface of the lumbar spine, a small perforation of the mediastinal pleura was seen Some lipomule was injected through the previously placed gastric tube and the fluid was again seen to flow through these perforations Posterior to this the pleura was divided and the mediastinal pleura reflected anteriorly Two intercostal vessels were divided between clamps just above the diaphragm In doing this the aorta was reflected anteriorly and beneath this there was seen a ductlike structure which appeared to be the thoracic duct At the region of the first lumbar vertebra there was some cystic dilatation By blunt and sharp dissection the duct was dissected superiorly and found to be one structure At this point it was divided between clamps and doubly ligated with silk By gentle dissection the duct was dissected inferiorly at the diaphragm At this point, however, it broke up into several branches A right angle clamp was placed across it at this point and the entire mass ligated en masse with double silk The specimen was removed for study There was some leakage of chyle, however, following this ligation it was thought possible that the surrounding small collaterals had been injured In order to obtain more reaction in the area some streptomycin powder was injected and some Gelfoam was placed at the s[illegible] amputation The mediastinal pleura was then closed snugly with interrupted silk sutures A drain was positioned laterally and placed under water drainage The right lung completely expanded under positive pressure The chest was closed in layers, using 0 chromic catgut throughout, with interrupted silk to close the skin The patient withstood the procedure fairly well and returned to his room in good condition One unit of blood and 500 c c of 1/6 molar lactate in 5 per cent glucose was used during the operation

The biopsy reported dated Sept 9, 1953 was as follows "The specimen consists of three portions of tissue One portion presents lobules of fat traversed by fibrous trabeculae and irregular channels These channels appear to have valves and present an irregular scanty distribution of muscle fibers within their walls There is also an incomplete cross section of a small artery and nerve trunk in this block of tissue A second portion of tissue presents focally a peripheral desiccation and in relation to this focus there is an irregular accumulation of lymphocytes The greater portion of the tissue consists of a collagenous matrix and small irregular lobules of fat Throughout the matrix there are numerous irregular clefts and channels These are of varying size Within some of the channels there can be seen linings of cells in others this is not definite In the surrounding collagenous matrix there is a scanty irregular distribution of muscle fibers In the two portions of submitted tissue the vessels seen are compatible with lymphatic vessels but whether this represents an abnormality in structure I cannot say There is no one large vessel but rather a plexiform arrangement of small vessels Diagnosis Vascular tissue "

Roentgenogram follow up on the next day Sept 6 1953, showed approximately 80 per cent collapse of the right lung with slight displacement of the mediastinal structures to the left indicating mild tension. There is little if any free fluid present A recheck film on Sept 7 1953, showed almost complete re-expansion of the right lung and a small amount of free fluid present On Sept 9, 1953 an x ray picture of the chest showed continuous good expansion of the right lung and the mediastinal structures in the midline There was a slight increase in the amount of fluid in the right pleural space since the previous study There were no hypostatic changes On Sept 15 1953 x ray films of the chest showed continued good expansion of the right lung There was little if any fluid remaining in the right pleural space but there was still some moderate pleural thickening

It might be mentioned here that on Aug 31 1953 a total protein determination showed 4 9 Gm per cent of which the serum albumin was 3 2 Gm per cent and the serum globulin was 1 7 Gm per cent On Aug 29 1953 the report on the fluid removed on July 30, 1953 was negative for tuberculosis after pig inoculation The patient made an uneventful recovery and was discharged on Sept 17, 1953

The patient was seen in the office on Dec. 11, 1953 He was feeling well. Weight was 58¾ pounds Fluoroscopically, the entire right lung was fully expanded The only abnormality seen was a thickening in the right lower area which somewhat obliterated the gutter

CONCLUSION

Successful ligation of a ruptured thoracic duct was carried out with complete cure in a boy, aged 7 years, who was struck in the abdomen by a blow of a fist A search of the literature failed to reveal another circumstance as this as the etiological factor With the numerous opportunities for this type of trauma, especially in boxing, it is strongly suggested that a contracoup blow may have ruptured the thoracic duct at a congenitally weak or defective area

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MITRAL COMMISSUROTOMY THROUGH THE RIGHT THORACIC APPROACH

TECHNIQUE AND INDICATIONS

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DURING the performance of surgery on the mitral valve in over 1,500 patients with rheumatic valvular heart disease,[1] several instances were encountered in which it would have been a distinct advantage to approach the mitral valve through the right hemithorax. This report is a description of a suitable technique and the indications for such an approach.

TECHNIQUE

A right thoracotomy is performed using either the posterolateral or anterior approach through the fourth intercostal space. After suitable exposure the pericardium is opened anterior to the phrenic nerve. The mitral commissurotomy is carried out through the left atrial wall as follows.

The superior vena cava is further mobilized by dissection posteriorly in the groove between the cavae and the left atrial chamber (sulcus terminalis). After dissection, the most lateral portion of the left atrium is exposed. Two parallel rows of stay sutures are placed in this portion of the left atrial wall. An encircling purse-string suture circumscribes this entire area (Fig. 1).

Using the stay sutures for hemostasis, a stab wound is made through the left atrial wall, and the operator's ungloved left index finger tip is inserted for exploration of the left atrial chamber and the mitral valve. If possible, the mitral commissurotomy is then carried out by finger pressure, but if necessary, an instrument can safely be used in this position although technically this procedure is more difficult than through the usual left auricular appendage approach (Fig. 2).

From this approach the relationship to the long axis of the mitral orifice is distinctly different from that of either the usual left anterolateral or posterolateral approach. Care in orientation is essential before attempting to open the valve.

After the mitral commissurotomy is completed the opening in the atrial wall is approximated (by alternately crossing the previously placed stay sutures) and is then repaired with a continuous everting mattress suture of 000 silk or cotton swedged on an atraumatic curved needle.

Following the mitral valvular surgery, any additional procedure is completed in the manner necessary.

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INDICATIONS

I *Associated Valvular Lesions*—Among the patients with mitral stenosis, several have been encountered with an associated tricuspid stenosis While it is true that the right atrium can be explored through the left hemithorax (during performance of the mitral commissurotomy), the procedure is difficult, and, if the tricuspid valve is leathery and resists finger pressure, as is the usual case, it is almost impossible to perform the tricuspid commissurotomy safely with an instrument (Although in a good many instances the mitral valve can be split by finger pressure alone, especially if calcified, the tricuspid valve rarely is calcified and in our experience, so far, has required cutting with an instrument in every instance)

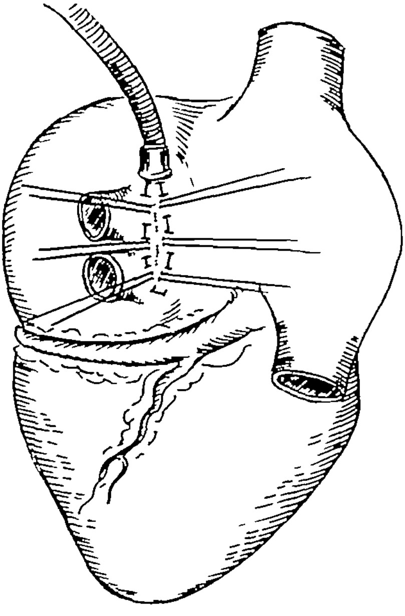

Fig 1

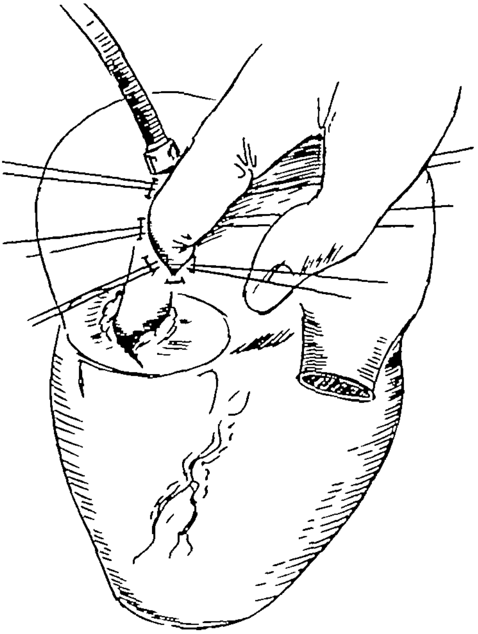

Fig 2

Fig 1—View of the right wall of the left atrium after dissection and placement of control sutures preparatory to exploration of the mitral valve.

Fig 2—View showing mitral commissurotomy being performed through the right lateral wall of the left atrium

Before the present right thoracic approach was used, patients with mitral and tricuspid stenosis were first treated by mitral commissurotomy through the usual left thoracic incision Then, at a later date, tricuspid commissurotomy was performed through the right thoracic approach[2] This not only required two operations, both of which were performed on a very ill patient, but also necessitated bilateral thoracotomy At the present time we are performing both operations simultaneously on such patients through an incision in the right hemithorax The tricuspid commissurotomy is done through the right auricular appendage (Fig 3), and then the mitral commissurotomy is performed by the method described.

II Associated Pulmonary Pathology—In the past we have encountered several patients with associated pulmonary pathology of various types Several patients with bronchiectasis, localized to the left side, have had combined mitral commissurotomy and pulmonary resection Although we have performed mitral surgery on patients with bronchiectasis localized to the right side, they have caused us the expected postoperative trouble due to increased secretions in spite of intensive medical management

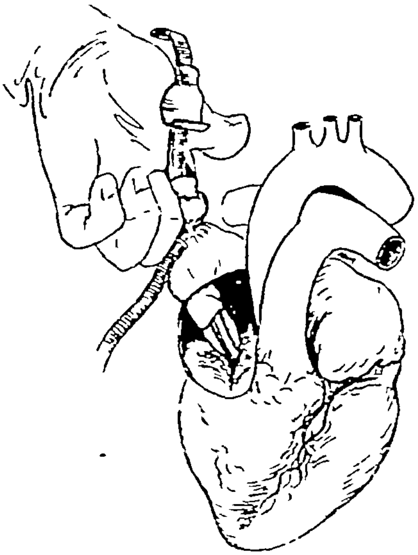

Fig 3 —Technique of tricuspid commissurotomy

In the future (when surgical treatment is deemed necessary) in patients needing mitral valvular surgery and having bronchiectasis localized to the right side the approach through the right hemithorax will be used If both procedures are performed, the patient not only should escape a second operation but also should have an easier postoperative course

Recently we had a patient with mitral stenosis and an obscure shadow in the right lung All preliminary studies were negative with regard to the pulmonary pathology, and since the mitral stenosis was not producing marked symptoms at the time, the right chest was explored first and an infarcted right middle lobe was found This lobe was resected, and postoperatively the patient had an extremely troublesome course due to cardiac complications The patient finally recovered and returned three months later for an uneventful mitral commissurotomy

With the present approach we have operated on an elderly, extremely ill patient with a somewhat similar roentgenographic lesion in the right lung This patient proved to have a bronchiogenic carcinoma, in the right upper lobe, although quite ill from a cardiologic view point he withstood, quite well simultaneous mitral commissurotomy and resection of the right upper lobe together with a block resection of the chest wall (Case 1)

III Associated Cardiac Anomalies.—Patients with Lutembacher's syndrome are ideal for such an approach. It is an easy matter to explore the mitral valve through the interatrial septal defect, and after commissurotomy the defect is repaired by the technique of atrio septo pexy which has previously been recorded (Fig. 4).[3, 4]

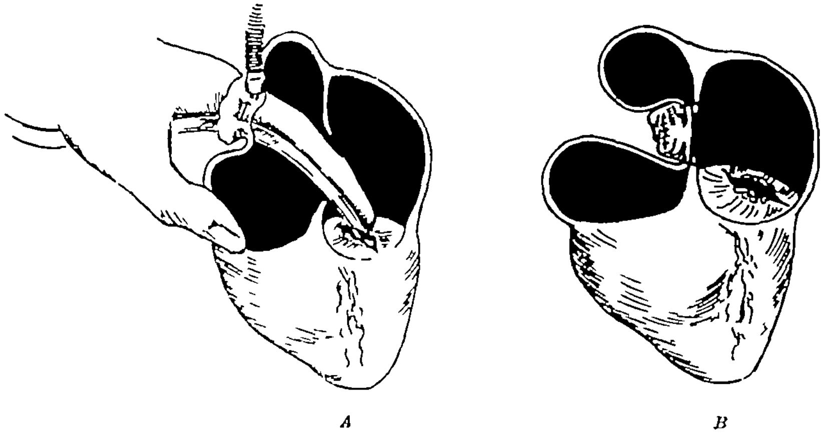

Fig. 4.—*A*, Mitral commissurotomy being performed through the interatrial septal defect. *B*, Closure of the septal defect by the technique of atrio septo pexy.

CASE REPORTS

CASE 1.—H. S. (H.H. 90968), a 55-year-old white man, entered Hahnemann Hospital on Aug. 20, 1953, complaining of three-pillow orthopnea of three months' duration, following, supposedly, a right pulmonary infarction.

Rheumatic fever had been diagnosed at the age of 13 years, and cardiac insufficiency had occurred three years before admission, the chief complaint had been dyspnea on exertion. This was fairly well controlled with digitalis. One year before admission he had suffered a left cerebral embolization with a repetition six months later on the right. Functional recovery from both had been excellent.

Physical examination revealed an orthopneic man with a pulse of 80, and blood pressure of 120 systolic and 90 diastolic. The cardiac rhythm was that of auricular fibrillation. The mitral first sound was sharp and accentuated. There was a midlate, rumbling diastolic murmur with presystolic accentuation best heard in the mitral area. The second pulmonic sound was accentuated.

Fluoroscopy and roentgen examination revealed an area of increased density in the posterior upper portion of the right lung field. The cardiac configuration revealed two plus enlargement of the right ventricle and left atrium (Fig. 5). There was also evidence of calcification of the mitral valve. The electrocardiogram revealed auricular fibrillation, right ventricular hypertrophy, and digitalis effect. Bronchoscopy showed no evidence of endobronchial disease, examination of bronchial secretions for tumor cells was negative.

The preoperative impression was rheumatic valvular heart disease with mitral stenosis and an undiagnosed parenchymal lesion in the right lung.

On Aug. 27, 1953, an exploratory operation was performed through a right lateral thoracic approach. The right lung was examined and a tumor was found to be present in the upper lobe with extension into the chest wall. The right upper lobe was resected together with a block of chest wall containing the third, fourth, and fifth ribs. Mitral commissurotomy was then carried out by the technique described. The mitral valve was found to be calcified and had an opening about 5 mm in diameter The valve was split by finger pressure to an opening of 25 mm in diameter without the production of any regurgitation.

The patient withstood surgery quite well Pathologic examination of the resected right upper lobe revealed squamous cell carcinoma, Grade III. He was discharged on Sept 12 1953 (sixteen days postoperatively), at which time he was considered to be in good general condition (Fig 6)

CASE 2—F F (H H 91086), a 39 year old white woman, entered the hospital on Aug 24, 1953 complaining of dyspnea and fatigability of ten years' duration and anasarca for three years' duration Abdominal paracentesis every two months had been necessary for the past year Rheumatic fever had been diagnosed at the age of 17 years She had been on a low salt diet mercurial diuretics, and digitalis

Physical examination revealed a blood pressure of 120 systolic and 70 diastolic Auricular fibrillation was present At the mitral area there were heard a sharp first sound and a midlate diastolic rumble with presystolic accentuation. In the tricuspid area, when the patient was placed in the right lateral position, there was a diastolic murmur which appeared to be different from that heard in the mitral area The lung fields were clear The liver was enlarged 5 cm below the costal margin Pitting edema of the lower extremities and evidence of abdominal fluid were also present

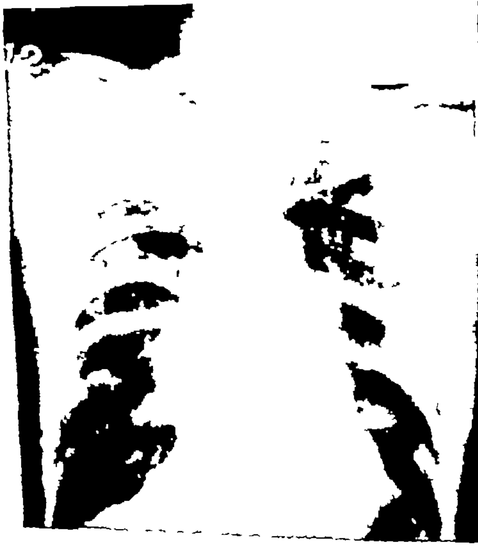

Fig 5

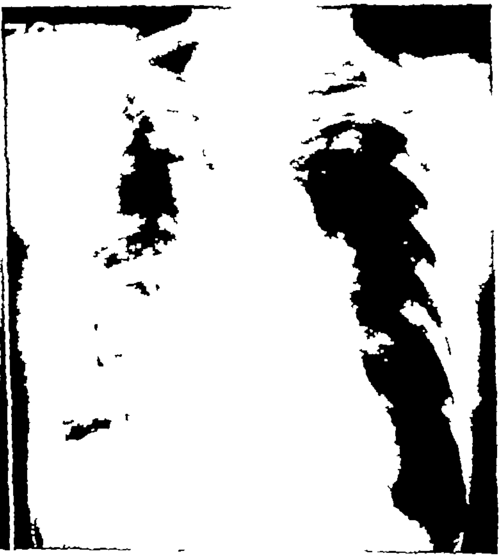

Fig 6

Fig 5—Preoperative roentgen view demonstrating the parenchymal lesion in the right upper lung field There is also the typical cardiac configuration of mitral stenosis

Fig 6—Postoperative view following simultaneous mitral commissurotomy and resection of the right upper lobe together with a portion of the chest wall

Fluoroscopy and roentgen examination showed an enlarged right ventricle and left atrium and questionable enlargement of the right atrium (Fig 7, A, B, and C) An electrocardiogram revealed right ventricular hypertrophy and auricular fibrillation The remaining laboratory examinations were normal On the basis of the clinical findings it was the preoperative opinion that this patient had combined tricuspid and mitral stenosis In view of the presence of auricular fibrillation it was not deemed of value to perform cardiac catheterization for physiologic evaluation of the tricuspid valve

On Aug 31, 1953 an exploratory operation was performed through the right thoracic approach The right atrium was found to be tremendously enlarged and the opening of the tricuspid valve was less than 10 mm in its longest diameter The valve was quite

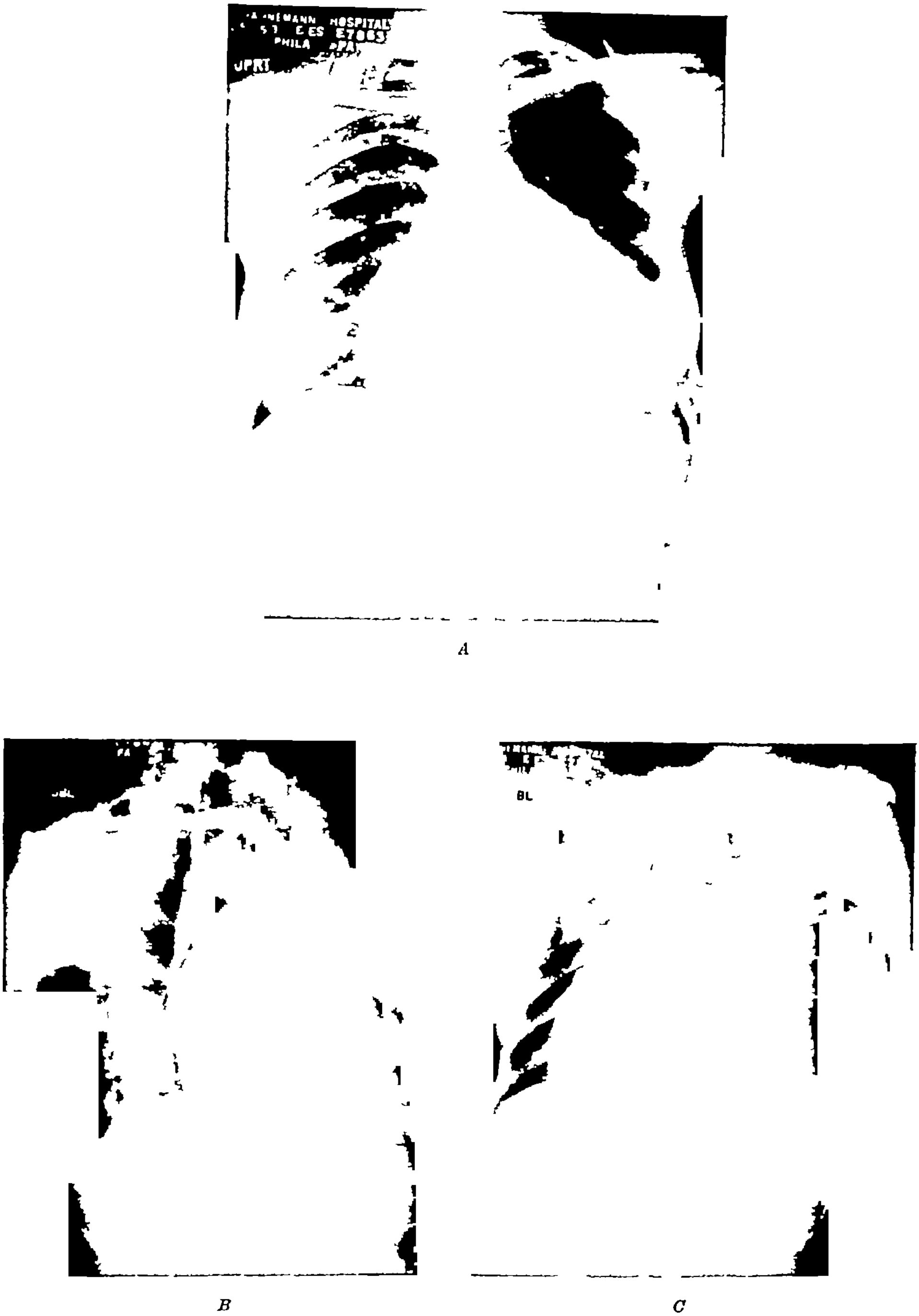

Fig 7 —*A* Preoperative view showing cardiac enlargement. *B* Demonstration of enlargement of the left atrium and right ventricular outflow tract *C* View showing enlargement of the right atrium

leathery and resisted commissurotomy by finger pressure alone, so the valve was cut with the guillotine knife until an opening of about 25 mm. was obtained Following tricuspid commissurotomy, the mitral valve was explored by dissecting the sulcus terminalis and passing the finger through the right wall of the left atrium. Its opening was found to be about 4 mm in diameter By means of commissurotomy an opening of about 18 to 20 mm was obtained without regurgitation

Postoperatively, the patient had a relatively uneventful hospital course She was discharged on Sept 29 1953, twenty nine days following surgery (Fig 8)

Case 3—J R[4] (Samaritan Hospital, São Paulo, Brazil), a 31 year old white man, entered the hospital with marked progressive physical incapacity and evidence of congestive heart failure of two years' duration

Physical examination revealed a sharp mitral first sound and a late diastolic rumble with presystolic accentuation. A systolic murmur was present over the entire precordium

Roentgen and fluoroscopic examination of the heart revealed marked cardiac enlargement Preoperative cardiac catheterization studies demonstrated a left to right shunt of 6 L per minute at the atrial level It was the preoperative opinion that the patient undoubtedly had Lutembacher's syndrome

On Feb 13, 1953, the patient was explored through the right thorax Digital exploration of the right atrium revealed a centrally located defect in the interatrial septum, about 3 cm. in diameter Examination of the mitral valve, through the septal defect, disclosed a very severe mitral stenosis Mitral commissurotomy was performed by finger pressure through the septal defect Atrio septo pexy was then accomplished in the manner previously reported The patient stood the procedure very well

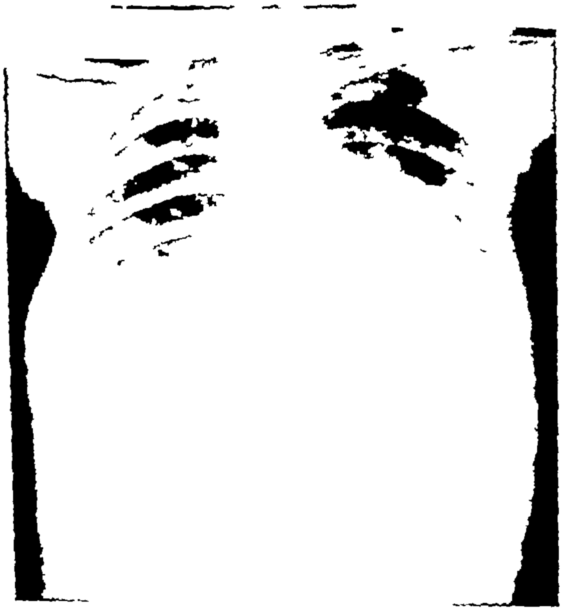

Fig 8—Postoperative view following mitral and tricuspid commissurotomy through the right thoracic approach

SUMMARY

1 A suitable technique for performing mitral commissurotomy through right thoracic approach is described The procedure is safe and practical

2 The indications are outlined By the use of such an approach, patients with mitral stenosis and associated lesions such as tricuspid stenosis, inter-

atrial septal defects, and pulmonary disease in the right lung can be treated completely at one operation This offers the obvious advantage to the patient of a single operation, and also, in many instances, actually increases the chance of survival by decreasing the chance of morbid complications

3 Three cases are reported in detail to demonstrate the indications and the desirability of such an approach

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UNUSUAL PROBLEMS IN MANAGEMENT OF CHEST WALL DEFECTS

REPORT OF TWO CASES

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DEFECTS of the chest wall most commonly follow replacement of normal structures by neoplastic tissue which in turn requires wide surgical excision. Less frequently, radiation necrosis produces extensive tissue loss. Much less frequently, trauma, followed by surgical treatment and complicated by infection may produce defects of major importance. According to Effler and Blades,[12] the low incidence of traumatic defects during World War II may be attributed to splendid early surgical therapy together with the use of antibiotics. These authors further state that, in most instances, the patient's regional tissues may be employed satisfactorily for closure without need of foreign material of various kinds.

Repair of defects of the superficial soft tissues of the chest wall does not involve surgical principles different from those followed in other parts of the body. However, when the bony structures of the cage are destroyed, problems peculiar to the repair of thoracic defects arise. In this article we have purposely omitted discussion of chest wall defects associated with existing bronchopleurocutaneous fistula since these latter situations demand additional attention to the underlying problem of origin and ablation of the fistula.

Lung hernias have been cured by simple pressure bandages[27] or by packing with irritant-soaked gauze.[15] As long ago as the end of the last century Tuffier[36, 37] repaired a lung hernia by simple ligation of the sac. Volger[38] later suggested the use of osteoperiosteal flaps which subsequently have been used by many other surgeons in the repair of chest wall defects.[1, 14, 18, 25, 27, 30]

Free rib segments have been used to stabilize the chest wall after operative correction of pectus excavatum. Dailey[9] was first to employ this method, which was subsequently used by others.[2, 10] Kirschner wires have been used for the same purpose.[26] Free rib segments have rarely been employed to stabilize the chest wall following other procedures.[11] Winkel,[40] in 1935, used woven fascia lata strips to anchor defect margins, while Watson and James[39] used large plaques of the same fascia anchored in place by interrupted sutures. Defects created by drainage of empyema cavities have been successfully lined by pedicle grafts.[4, 28]

Campbell[8] reported a clever method for reconstruction of anterior chest wall defects by using the latissimus dorsi muscle. As a prerequisite for success of this method, the subscapular vessels must be intact. The pectoralis major muscle has also been utilized to bridge anterior wall defects.[23] The mobilized female breast was first used to close a chest wall defect by Sauerbruch.[33] Re-

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cently Maier,[24] Pickrell and his associates,[31 32] and others[20] have had gratifying success with this procedure Pickrell[31 32] reported the use of a free split thickness graft applied directly upon the anterior pericardium after resection of the lower sternum and costal cage Urban[37] and Pickrell[31 32] have recorded nice results using adjacent thoracic and abdominal soft tissue flaps One of us (T D C) has successfully employed such flaps to repair defects of the anterior chest wall following excision of radionecrotic and malignant tissue, the result of breast disease

Tantalum plates have been employed in rare instances but without striking success[3 7 16 30] In general, the plate method has been abandoned

Tantalum and/or stainless steel mesh gauze have been used with real satisfaction by numbers of surgeons[1 11, 20 28] In general, of the foreign materials employed, the metallic mesh has been most satisfactory

The reports here presented concern two patients in each of whom trauma with superimposed infection, followed by surgical therapy, resulted in a large incapacitating defect of the chest wall

CASE REPORTS

CASE 1 —E A , a 38 year old white man, was admitted to Veterans Administration Hospital, Houston, Texas, on Sept 14, 1949, with a history of having received a penetrating, small caliber missile wound of the left chest while in combat in 1944 The left chest was explored and drained, soon after the injury Postoperatively the patient developed an empyema manifest by drainage of purulent exudate from the left chest Because of persistence of drainage, together with hemoptysis, a partial thoracoplasty was done Following this procedure he did well with the exception of repeated small episodes of hemoptysis, weakness, and dyspnea In April, 1949, he experienced a severe pulmonary hemorrhage The presenting complaint was a small episode of pulmonary bleeding three days before admission

Physical Examination.—The patient was a poorly nourished white man who appeared chronically ill Vital signs were normal There was marked deformity of the left chest with partial absence of the anterior or lateral aspects of ribs, two through nine inclusive. The old thoracoplasty scars and gunshot wounds were well healed There was marked limitation of motion of the left chest with dullness on percussion Bronchial breath sounds with crackling râles were heard over the left lung The remainder of the physical examination was noncontributory

Accessory Clinical Findings.—Laboratory findings were all within normal limits These included repeated negative sputum studies for tubercle bacilli

Course in the Hospital.—Chest roentgenograms at the time of admission revealed an absence with partial regeneration of the left second, third, and fourth ribs anteriorly and the fifth, sixth, seventh, eighth, and ninth ribs laterally Clear lung areas were noted in the apical portion on the left with a slight shift of the heart and mediastinum to the right X ray appearance suggested that a partial pulmonary resection had been done followed by thoracoplasty Bronchographic examination, on the other hand, showed filling of the entire left lung with marked compression of the basilar segments (Fig 1) Bronchoscopic examination revealed active bleeding from the left upper lobe

On Oct 24, 1949, an exploration of the left hemithorax revealed a dense, scarred, spherical mass in the lower portion of the left upper lobe which contained a foreign body, thought to be a piece of camouflage net Small loculations of purulent exudate were encountered The left lung was collapsed and nonaerated A pneumonectomy was performed Postoperatively the patient developed a spiking temperature and evidence of empyema Purulent exudate was aspirated from which *Staphylococcus aureus* was cultured The patient was treated with antibiotics, repeated irrigation of the chest cavity, and finally by open drainage The general

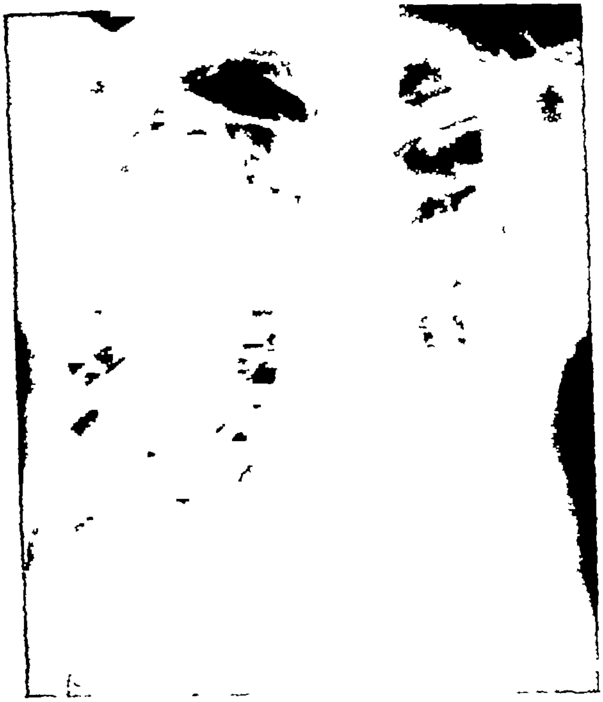

Fig 1 (Case 1)—A bronchogram done soon after admission revealed the presence of both lobes on the left with diminution in size of the left pleural space

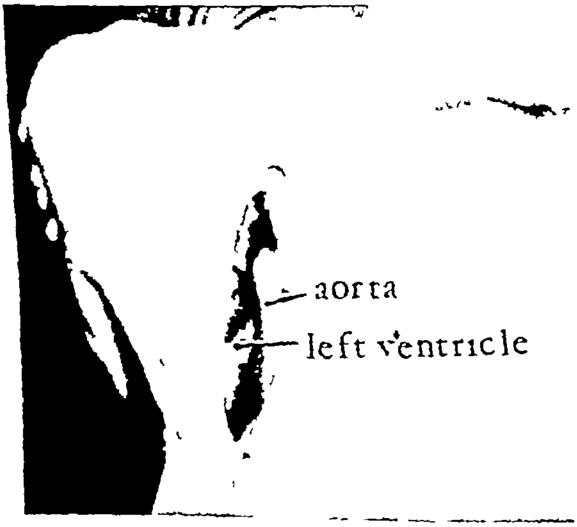

Fig 2 (Case 1)—The aorta and left side of the heart are clearly seen in this late photograph taken over one year after completion of chest wall surgery

condition, thereafter, improved Several focal revisions of the thoracoplasty wound were done, the space was irrigated and packed These operations left an unroofed, narrow, deep cleft in the left hemithorax, bounded medially by the mediastinum and vertebral bodies and laterally by the subscapular tissue and regenerated rib segments In spite of these procedures, it appeared that the defect would not heal by secondary intention and therefore, on Sept 7, 1950, a split thickness skin graft was applied within the granulation tissue-lined defect The split thickness skin graft took well Later minor revisions included excision of the scapula tip before complete, permanent wound closure was obtained (Fig 2)

CASE 2—J A. M, a 49 year old white man, was admitted to the Veterans Administration Hospital, Houston, Texas, on March 24, 1951, with complaints of chronic cough and dyspnea In 1918, while in combat in France, he received a gunshot wound of the right chest He was discharged after nine months' hospitalization, but continued to have a chronic cough In 1928, ten years after his injury, a right lung abscess was demonstrated This was treated by repeated aspirations but he remained chronically ill with frequent febrile episodes In 1947, a right pneumonectomy was performed at a Navy hospital On the fifth postoperative day, there was a blowout of the bronchial stump This was treated by closed thoracotomy drainage for nine months He was transferred to the Veterans Hospital, McKinney, Texas, weighing 87 pounds, in February, 1948, a Schede type thoracoplasty with closure of the bronchial stump was done Following this procedure, drainage stopped but the patient had marked respiratory distress, this was complicated by asthma

Physical examination on arrival at our hospital revealed a chronically ill man, moderately dyspneic even at bed rest There was marked asymmetry of the thorax There was an old scar from the previous thoracoplasty, which extended from the superior border of the scapula posteriorly to the sixth rib anteriorly, there was marked depression of the right side of the chest Movements of the chest wall on respiration were paradoxical On the right side, the heart was covered only by skin, subcutaneous tissue and pericardium and the pulsations were quite prominent No ribs could be palpated laterally above the level of the tenth On inspiration there was a shift of the lower ribs medially (Fig 3) The remainder of the physical examination was noncontributory

Accessory Clinical Findings—Chest roentgenograms revealed evidence of an extensive thoracoplasty on the right with minimal bony rib regeneration (Fig 4) There were no lung markings on the right side The left lung was clear and, indeed, perhaps overaerated Fluoroscopy revealed considerable mobility of the mediastinum There was marked irregularity in the descent of the diaphragm on the right side with respiratory excursions In addition, inefficient use of the left diaphragm was also noted With external support of the right chest, better function of the left diaphragm and better stabilization of the mediastinum were noted Respiratory studies were made and revealed marked impairment of function. copy revealed considerable mobility of the mediastinum. There was marked irregularity in Because of the paradoxical movements of the chest wall, which had not been reduced materially by corsets, an attempt at stabilization seemed desirable This was done on July 13, 1951

The old scar was excised and skin and subcutaneous tissue flaps were freed from the subjacent pericardium The fourth costal cartilage was excised exposing the border of the sternum, the body of the eighth thoracic vertebra was exposed posteriorly

The eleventh and twelfth ribs were then removed through an accessory oblique incision, following which these ribs were inserted as bony struts The eleventh rib was attached posteriorly to the eighth vertebral body with two screws, its anterior end was attached with stainless steel wire to the lateral edge of the sternum at the site of removal of the fourth costal cartilage The twelfth rib was then bridged between the middle of the newly transplanted eleventh rib and the undisturbed tenth rib, thus forming a "Y" The attachment between ribs was accomplished with stainless steel wire The wound was then closed in layers with a drain beneath the flap A pressure dressing was applied Postoperatively, the patient did well and the dyspnea was greatly improved (Fig 5)

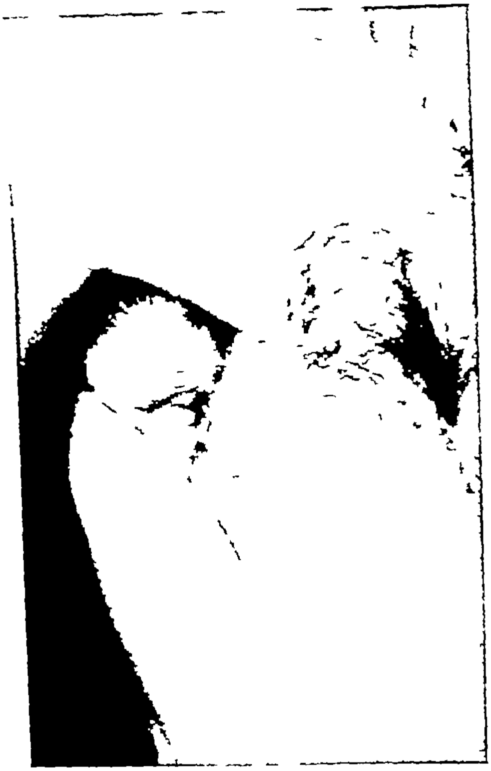

Fig. 3 (Case 2) —The depression of the chest wall on inspiration is readily apparent.

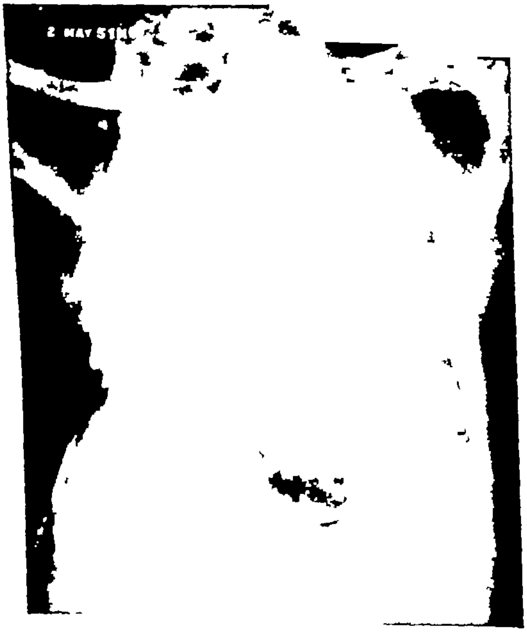

Fig. 4 (Case [illegible]) This film illustrates the status of the bony chest wall at the time of admission.

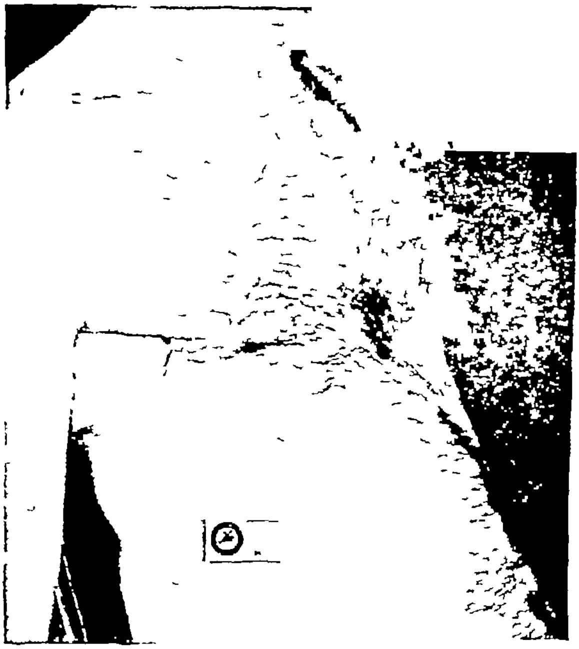

Fig 5 (Case 2) —This photograph also taken during inspiration was made several months postoperatively Note the absence of the marked depression which existed before operation

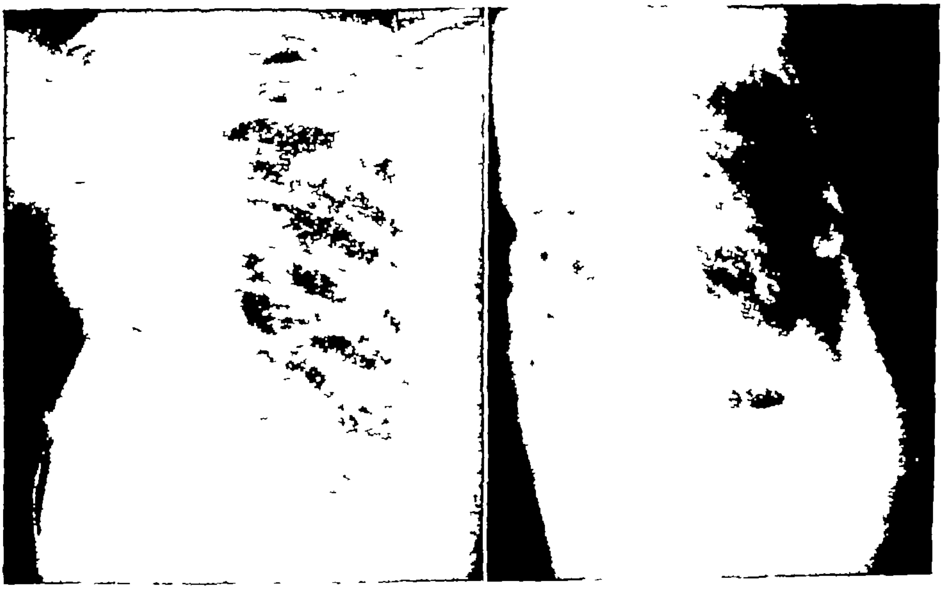

Fig 6 (Case 2) —These films show the rib struts in place. Similar films made a year later show no change.

He was last seen on Sept 16, 1955, two years following operation, at which time he was cheerful and stated he was much better than before the reconstructive procedure He was free of dyspnea at rest and even with slight activity but he has little respiratory reserve and becomes dyspneic on moderate exertion. The rib grafts are still in place as shown by palpation and x ray films (Fig 6) He has slight motion just below the rib grafts, and there is still some medial displacement of the lower cage on inspiration

DISCUSSION

In Case I, a difficult problem was finally solved in a relatively simple fashion After attempts to obliterate the space by collapse measures had failed the space was marsupialized No previous mention of the use of split skin grafts for this purpose has been found though pedicle flaps have been employed The method has the disadvantage of leaving an unsightly deformity

The problem involved in the second case was paradoxical motion of the chest wall This sometimes becomes a factor of great importance when a large section of the rib cage is removed In our review of the literature we found only rare instances in which free rib grafts were employed in reconstruction of the chest wall While the use of autogenous material seems desirable, it is reasonable to suppose that bank bone might be used to advantage for this purpose

SUMMARY

The recent literature on management of chest wall defects has been reviewed Two illustrative case reports have been presented

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PRESSURE BREATHING IN SURGERY

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PRESSURE breathing is the control of respiratory dynamics by the deliberate alteration of intrapulmonary pressure It is most commonly produced by the application of pressure by means of a mask or an endotracheal tube Through pressure variations one can control respiratory exchange facilitate surgical procedures or under certain circumstances stabilize circulatory function

Pressure breathing is used in artificial respiration to improve ventilation It is employed during general anesthesia where powerful relaxant drugs have been used to facilitate surgery Here the anesthetist may attempt to maintain satisfactory ventilation by aiding the inspiratory effort of the patient This is termed 'assisted respiration or the anesthetist may render the patient apneic and assume responsibility for the rate as well as the volume of ventilation This is known as controlled respiration The open chest in the majority of instances adversely affects respiratory dynamics Pressure breathing is therefore also indicated in this situation

There seems to be very little criticism of the need for pressure breathing There is however much that can be said against its application for if it is improperly applied the patient may be injured

Although pressure breathing had long been employed for resuscitation it was not until the advent of surgical entrance into the thoracic cage that it was employed in surgery Surgeons have played an important part not only in recognizing the need for pressure breathing but also in the development of pressure breathing apparatus Mikulicz in 1903 recognizing that intrathoracic surgery could not progress until the hazards of an open thorax could be overcome commissioned his student Sauerbruch to resolve the problem Sauerbruch[11] recognizing the need for some form of pressure breathing built and in the following year presented the pressure chamber known by his name (Fig 1) The patient s body is within the negative pressure cabinet The patient s head extends into the surrounding room This diagram of the Sauerbruch cabinet is extremely interesting It reveals perhaps in some new manner the brilliance of Sauerbruch As you may note the lower part of the patient s body is in communication with the outside room and is thus maintained at atmospheric pressure One must therefore assume that Sauerbruch was familiar with something that we have but recently begun to appreciate that is that in our endeavor to prevent the

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hazards of pneumothorax by pressure breathing, we introduce new dangers. It is also evident that he appreciated the desirability of not interfering with venous return to the right heart under these circumstances.

In 1908 Meyer[8] presented his double chamber apparatus (Fig. 2). The patient's body is maintained under negative pressure and the patient's head is in a positive pressure cabinet. It seems clear that Meyer either did not believe, or failed to appreciate, some of the deleterious effects of pressure breathing which were of such vital concern to Sauerbruch. It is perhaps of particular interest to this group that Murphy[9] and Robinson,[10] and associates,[10] all in Boston, contributed to the literature on pressure breathing by the creation and description of new apparatus.

After the early years the progress in pressure breathing rested to a large extent in the hands of the anesthesiologist. An important advance was the development of controlled respiration, that is, the production of apnea and ventilation by manual bag compression. A surgeon, Crafoord,[1] devised a mechanical means for controlled respiration, and, more recently, Maloney and associates[4-] have contributed much to this important subject.

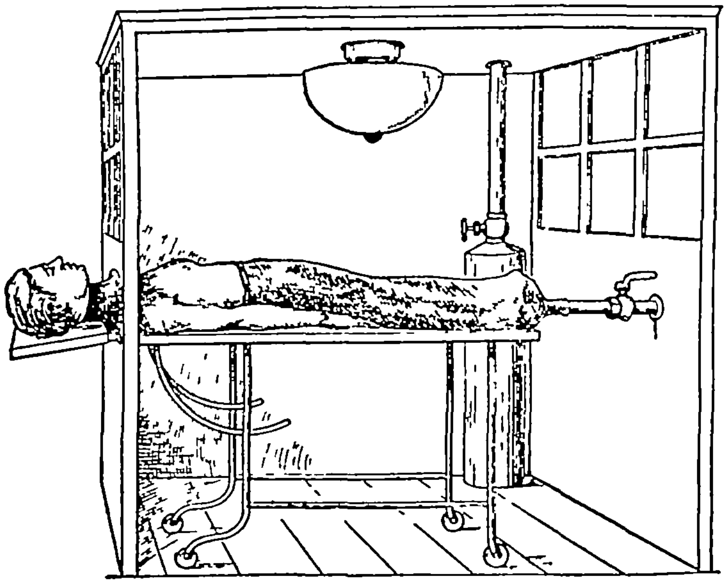


Fig. 1.—Sauerbruch cabinet. Position of patient in chamber ready for operation under negative pressure.

It is perhaps important to review the possible effects of increased intrapulmonary pressure on a physiologic basis. In the seventeenth century Valsalva recognized that *increased intrapulmonary pressure* interfered with the flow of blood through the lungs. He determined that " . . . if, after a deep inspiration, a strenuous and prolonged expiratory effort be made against a closed glottis, the pressure so exerted on the heart and greater vessels, arrests the flow of blood through the lungs." That such increased intrapulmonary pressure can cause a fall in arterial pressure was noted by Embrodt. He stated that positive pressure breathing produces a great fall in arterial pressure due to the inability of blood to enter the thoracic cavity so that the heart becomes depleted and its output falls. Weber[12] stated 'I discovered I could interrupt at will for a moment the beats of my heart and the pulsation of my arteries by hindering the air from entering into my chest which I was at the same time compressing.

Fig. —Willy Meyer double chamber apparatus

More recently many have shown that positive pressure breathing results in a diminution in cardiac output. The mechanism seems to be clear (Fig 3). We note from the right side of this drawing that increased intrapulmonary pressure produces an increased vascular resistance because of direct pressure upon the capillaries within the lungs. Interference with the perfusion of blood across the capillaries of the lung results in a decreased left ventricular filling. A decrease in left ventricular filling is followed by a decrease in cardiac output. On the left portion of the drawing we note that increased intrapulmonary pressure causes cardiac tamponade. Tamponade results in poor filling of the right heart, this in turn means a decreased perfusion of blood across the pulmonary capillary bed, followed in turn by a decrease in left ventricular filling and a consequent decrease in cardiac output. It is important to note that since right atrial pressure is increased, there is a backing up of venous blood with an elevation of venous pressure.

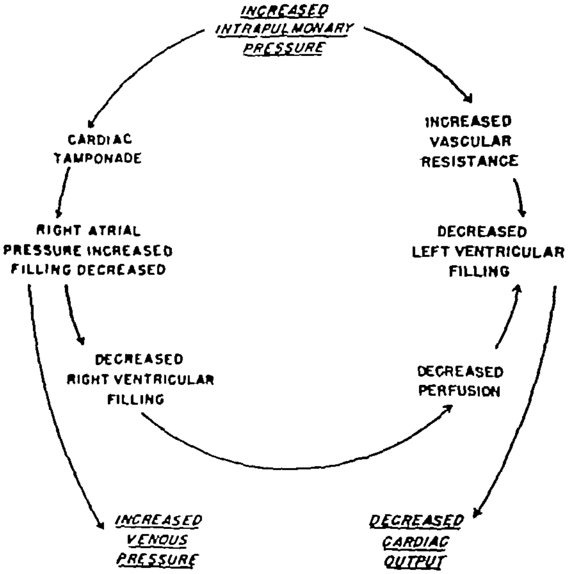

INCREASED INTRAPULMONARY PRESSURE
INCREASED VASCULAR RESISTANCE
DECREASED LEFT VENTRICULAR FILLING
DECREASED PERFUSION
DECREASED CARDIAC OUTPUT
CARDIAC TAMPONADE
RIGHT ATRIAL PRESSURE INCREASED FILLING DECREASED
DECREASED RIGHT VENTRICULAR FILLING
INCREASED VENOUS PRESSURE

Fig. 3.—Effect of increased intrapulmonary pressure on cardiac output and venous pressure.

The patient in good condition can tolerate a moderate amount of increased intrapulmonary pressure. The patient in a poor physical state cannot. The ability to withstand positive pressure breathing depends to a great extent on the patient's ability to maintain a heightened venous pressure, for, during the phasic drop in intrapulmonary pressure, the elevated venous pressure is an important factor in filling the right heart. It thus contributes to the maintenance of a satisfactory cardiac output. Nothing should be done which will interfere with the patient's ability to develop and maintain an elevated venous pressure.

Ganglionic blockade effectively prevents the patient from elevating his venous pressure. Thus, ganglionic blockade as for hypotensive anesthesia, or by spinal or paravertebral block, renders these patients poor candidates for pressure breathing. It has been established beyond doubt that hypovolemic patients tolerate pressure breathing extremely poorly. These patients are incapable of maintaining a satisfactory venous pressure, let alone being able to elevate it. Blood loss in a patient under pressure breathing is a hazard out of all proportion to the amount of blood lost and in these patients particularly blood replacement is vital and should not be delayed. It should be anticipated.

Since pressure breathing is an important aid to some forms of abdominal surgery and a vital adjunct to intrathoracic surgery means to decrease its hazard should be employed

The effect of pressure breathing on cardiac output seems to be in direct ratio to the mean pressure The greater the mean pressure the greater is the effect on cardiac output The mean pressure can be lowered by intermittently permitting the intrapulmonary pressure to drop to ambient pressure The

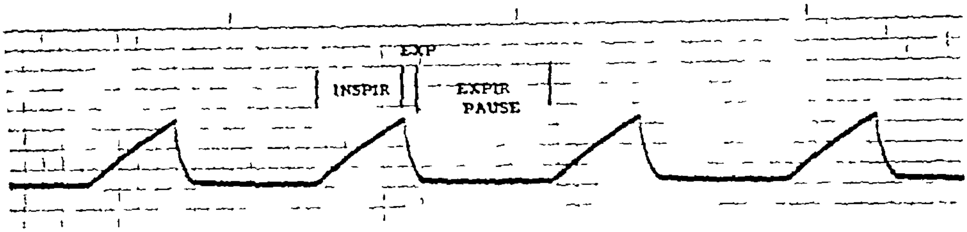
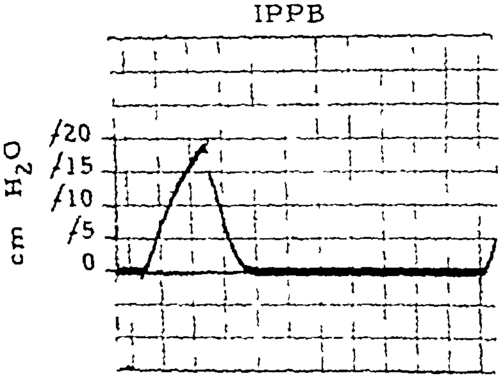


Fig 4 —Phases of inspiratory positive pressure respiration



Inspiration	8 sec
Expiration	3 28 sec
Peak pressure	19 cm H_2O
Mean pressure	12 66 cm H_2O

Fig — Inspiratory positive pressure respiration with low mean pressure

duration of expiration should be longer than the period of inspiration to allow the heart to catch up during this period of phasic decrease in intrapulmonary pressure (Fig 4) This latter is more easily accomplished in controlled than in assisted respiration

A protracted period of elevated intrapulmonary pressure produces deleterious effects on circulation and gas exchange It is the practice of many thoracic surgeons to request such a period of heightened intrapulmonary pressure Request is made of the anesthetist during the closure of the chest to bring the lung to the chest wall and keep it there through the period of such closure Of all the circumstances and of all the times that a high mean

Fig 6

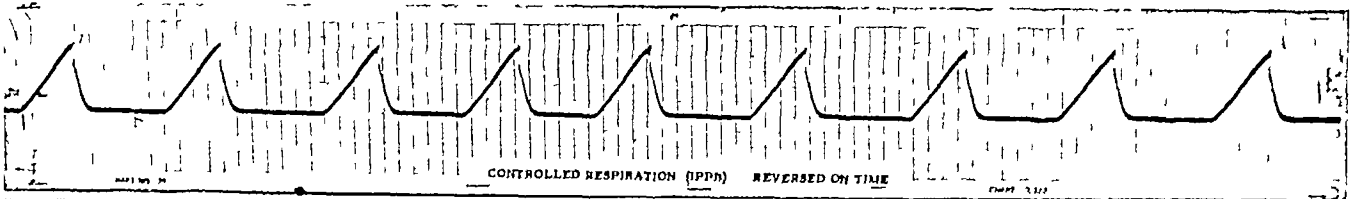


Fig 7

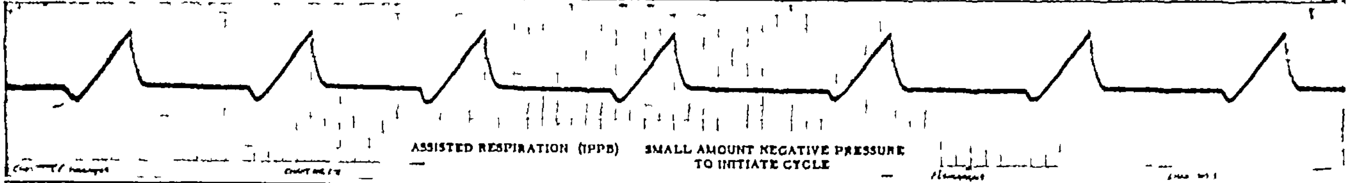


Fig 8

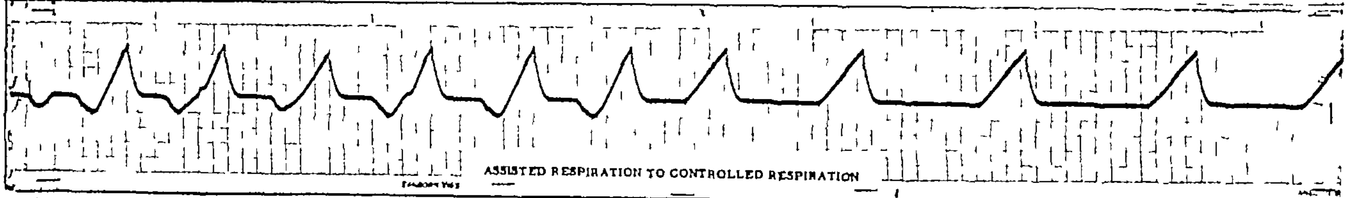


Fig 9

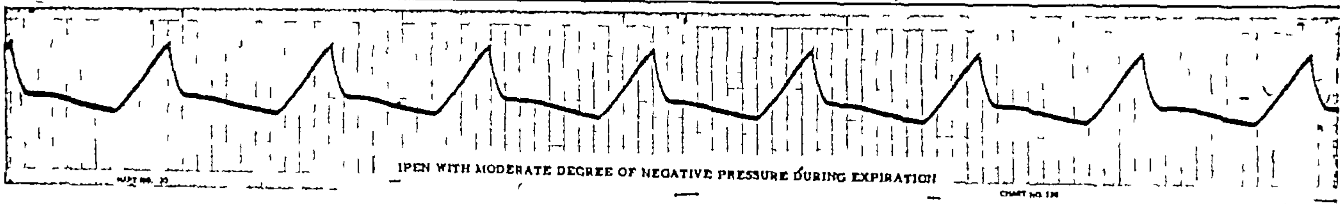


Fig 6—Controlled respiration inspiratory positive pressure breathing
Fig 7—*Assisted respiration inspiratory positive pressure breathing*
Fig 8—Assisted to controlled respiration
Fig 9—Controlled respiration inspiratory positive expiratory negative pressure breathing

[illegible] respiratory pressure may be particularly harmful none exceeds this set of conditions. It is especially at this time that nothing should be done further to compromise the patient. It is our experience that chest walls can be safely closed and pneumothorax be prevented by intermittent insufflation of the lung and by chest aspiration.

During thoracic surgery occasional inflation of the atelectatic lung is desirable. The collapsed portion of the lung should be inflated carefully by intermittent positive pressure breathing with increasing increments of pressure at the peak of inspiration. Rapid inflation of the lung by constant positive pressure is undesirable and harmful.

Lung motion sometimes interferes with smooth and rapid progress during chest surgery. Lung motion often reflects tidal exchange. It may be [illegible] even with small tidal exchanges the patient's degree of oxygenation may be satisfactorily maintained. The more difficult problem however is satisfactory carbon dioxide elimination. This is dependent upon good tidal volume. Minimal lung movement means unsatisfactory gaseous exchange. As a result a very large proportion of intrapulmonary surgery is done on patients suffering with marked respiratory acidosis.

Artificial respiration in the operating room for collapse due to overdose [illegible] relaxants too high a spinal anesthesia trauma or when [illegible] for cardiac arrest can of itself seriously interfere with the [illegible] of recovery because of the effect of inspiratory positive [illegible] breathing on cardiac output.

It [illegible] positive pressure breathing of the proper sort may be carried [illegible] of the bag or by mechanical means. It is our [illegible] the patient can be better maintained on controlled or assisted [illegible] mechanical device. We have constructed an electronically [illegible] apparatus which employs oxygen alone or oxygen in combination [illegible] which can produce any desired respiratory pattern. [illegible] under full control one can produce satisfactory [illegible] pressure (Fig. [illegible]). It can produce controlled [illegible] alone (Fig. 7) or a combination of [illegible] (Fig. 8). The apparatus can sense [illegible] this record.

[illegible] studies is an important negative [illegible] the right heart. Artificial respiration [illegible] pressure breathing is [illegible] simply [illegible] venous return [illegible]

Fig 6

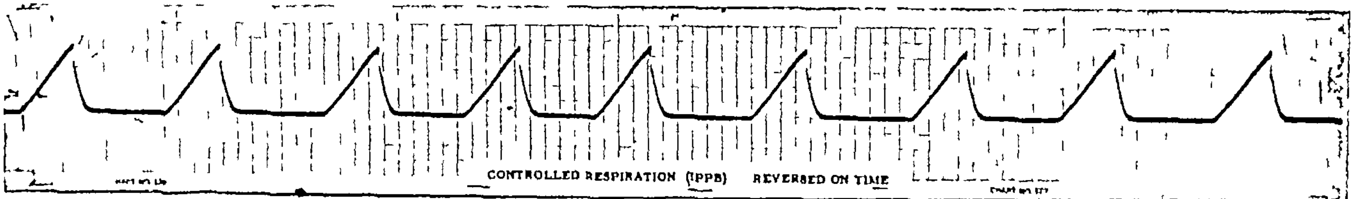


Fig 7

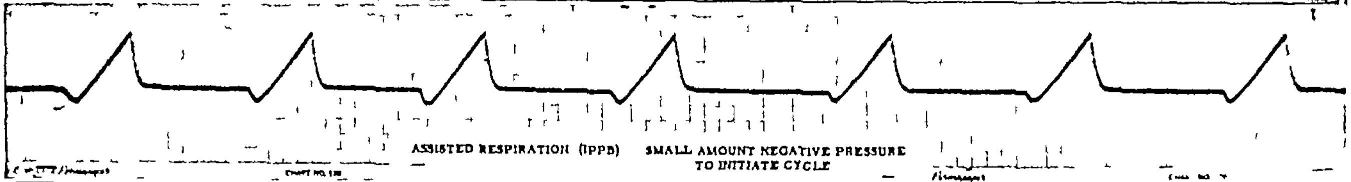


Fig 8

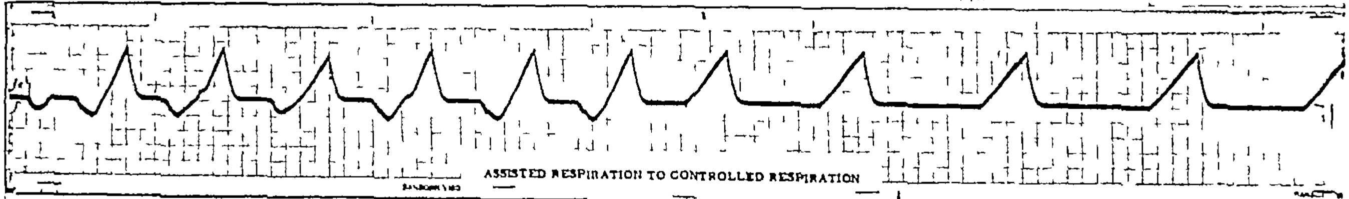


Fig 9

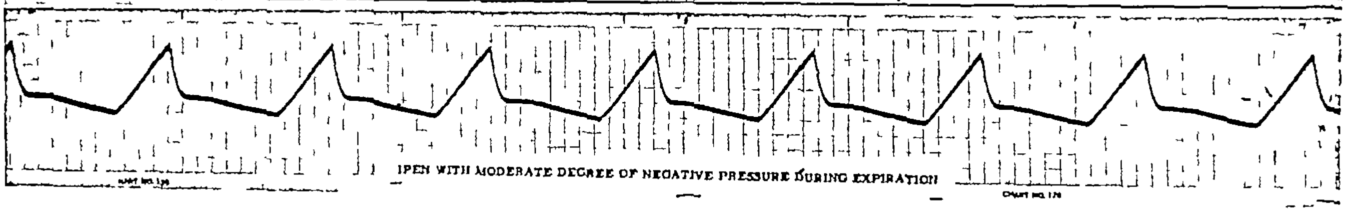


Fig 6.—Controlled respiration inspiratory positive pressure breathing
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Lung motion sometimes interferes with smooth and rapid progress during chest surgery Lung motion often reflects tidal exchange It may be true that even with small tidal exchanges the patient s degree of oxygenation may be satisfactorily maintained The more difficult problem however is satisfactory carbon dioxide elimination This is dependent upon good tidal volume Minimal lung movement means unsatisfactory gaseous exchange As a result, a very large proportion of intrapulmonary surgery is done on patients suffering with marked respiratory acidosis

Artificial respiration in the operating room for collapse due to overdose of anesthetics or relaxants too high a spinal anesthesia trauma or when carried out for cardiac arrest can of itself seriously interfere with the patient s chance of recovery because of the effect of inspiratory positive pressure breathing on cardiac output

Inspiratory positive pressure breathing of the proper sort may be carried out by manual compression of the bag or by mechanical means It is our belief that the patient can be better maintained on controlled or assisted respiration by a mechanical device We have constructed an electronically controlled apparatus which employs oxygen alone or oxygen in combination with anesthetic gases and which can produce any desired respiratory pattern With each of the variables under full control one can produce satisfactory tidal exchange with a low mean pressure (Fig 5) It can produce controlled respiration alone (Fig 6) assisted alone (Fig 7) or a combination of assisted and controlled respiration (Fig 8) The apparatus can sense an effort by the patient to inspire and it aids him in this regard

Normal respiration because of a phasic decrease in intrapleural negative pressure encourages return of blood to the right heart Artificial creation of a phase of negative pressure in pressure breathing is becoming increasingly important for it not only lowers the mean pressure but it aids venous return This should be of great value in hypotensive states as in shock A negative pressure phase may be introduced in the apparatus (Fig 9)

SUMMARY

Pressure breathing as fostered by surgeons is a vital adjunct to present-day surgery and anesthesia Its tremendous benefits may often be offset by some of its deleterious effects These effects must be anticipated recognized and treated To obtain maximum advantage of pressure breathing with a minimum of harmful effects will require the utmost cooperation between the surgeon and the anesthetist

Please consider this presentation my personal plea to this end

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CONGENITAL TRACHEOESOPHAGEAL FISTULA WITHOUT ATRESIA OF THE ESOPHAGUS

K S Mullard, M D
London, England

A BROAD survey of congenital abnormalities shows that developmental failure is rarely seen in its most severe form, but that lesser degrees of the same fundamental error of development are common Spina bifida occulta is common, meningomyelocele is rare Complete exomphalos is rare umbilical hernia is common Complete bilateral harelip and cleft palate are far less common than their many minor variants Many such examples come to mind

It is surprising, then, that while many hundreds of cases of congenital atresia of the esophagus, with tracheoesophageal fistula are recorded,[1-3] and very many more are known, but are no longer recorded, there are very few records of minor variants of this congenital abnormality, such as atresia or stenosis of the esophagus without fistula, or fistula without atresia

There are two possible reasons for this One is that minor variants occur, but are not diagnosed The second is that the error of development is peculiar in that it can give rise only to the full-blown lesion of fistula with atresia, and minor variants cannot occur

It is the purpose of this paper to suggest that at least one minor variant, fistula without atresia, does occur, but is not diagnosed and may be far more common than is thought at the present time

To dispose of the second possibility, it is necessary to review the development of the trachea and esophagus, and to consider the various theories that have been put forward to account for the widely known congenital lesion of fistula with atresia

EMBRYOLOGY

Vogt's classification of the congenital abnormalities of fistula and atresia is well known, as is the fact that Type III(b) occurs far more commonly than the other variants (Fig 1) Many theories have been put forward to account for these developmental errors Pressure by the heart and pericardium, a prominent feature of the developing embryo has been suggested The primitive arterial arches and the great veins, have been incriminated But none of these pressure theories explains the marked preponderance of Type III(b) The most attractive theory is that of Gruenwald[4] who has described a case of fistula with atresia in a 9 mm human embryo He pointed out that normally the trachea is developed as a ventral outgrowth from the foregut, and from that part of the foregut which is to become the esophagus (Fig 2) It is an embryologic maxim that when a parent tube gives rise to a daughter tube, it does so at the temporary expense of its own lumen, and it is reasonable to assume,

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although this is not known for certain, that during the phase of budding off of the trachea, the esophageal lumen becomes blocked by proliferating cells. When the trachea has separated from the esophagus, the next phase of development is a rapid elongation of the trachea. It elongates not only in proportion to the growth of the embryo as a whole, but in excess of this proportion, so

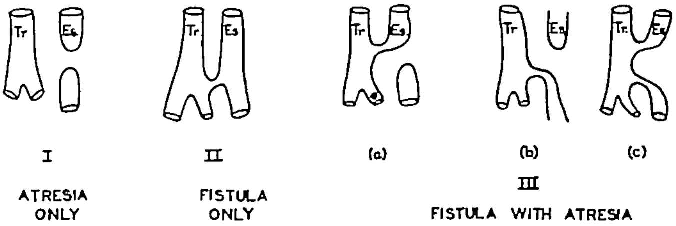

Fig 1.—Vogt's classification of congenital fistula and atresia. Type III (b) preponderates and is widely reported following surgical correction.

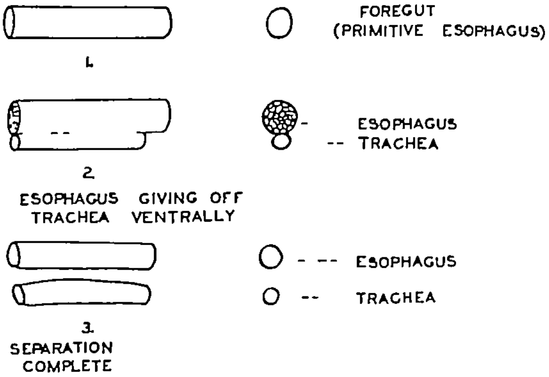
1.
FOREGUT (PRIMITIVE ESOPHAGUS)
2.
ESOPHAGUS
TRACHEA
ESOPHAGUS GIVING OFF TRACHEA VENTRALLY
ESOPHAGUS
TRACHEA
3.
SEPARATION COMPLETE

Fig 2.—Following the separation of the trachea from the esophagus there is a rapid caudal elongation of the trachea.

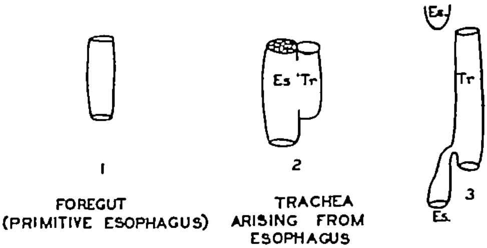

Fig 3.—The rapid elongation of the trachea takes place before the trachea and esophagus have separated (that is at Phase 2) and the esophagus is attenuated on the posterior wall of the trachea (3) to produce Type III (b) deformity of Vogt. (After Gruenwald.)

that it elongates relatively to the esophagus, which, of course, is also growing in proportion with the whole embryo. Gruenwald held that the usual anomaly, fistula with atresia, Type III(b), is due to the failure of coordination of the two phases of development, so that the rapid elongation of the trachea takes place before the trachea becomes separated from the esophagus (Fig 3). In this event, the esophagus, its lumen probably blocked by cells, will be drawn out along the posterior wall of the trachea as an attenuated strip, or as a thin cord, or fragmented. The site of the fistula between the lower end of the esophagus and the trachea will depend upon the degree of separation between the two at the time that caudal elongation of the trachea takes place. If this rapid growth takes place at an early stage, then the fistula will be near the carina, but if separation is almost complete then the fistula will be high in the trachea.

Gruenwald considered that the upper blind pouch is produced by the growth of a part of the primordial esophagus attached to the pharynx. His theory is reinforced by the discovery of squamous epithelium and striated muscle in the posterior wall of the trachea in cases of fistula and atresia.[6, 7] Rosenthal[8] has observed a case in which the esophagus was visible as a longitudinal thickening on the posterior wall of the trachea. I have observed, in cases of patients with fistula with atresia on whom I have operated, that there is a clear angle between the trachea and esophagus below the fistula, but that above it, there is often a band or cord running up the posterior wall of the trachea for a variable distance, making the fistula difficult to define at this point. Many other surgeons performing these operations must also have observed this, but its significance becomes apparent only with the background of Gruenwald's theory.

Gruenwald pointed out that esophageal remnants may not be found in the posterior wall of the trachea. This does not affect the validity of his theory, since it is well known that intercalated structures such as grafts, may be incorporated in the final structure of an organ, in so far as their fundamental structure allows transformation under the influence of the anlage of the developing parent organ.

Gruenwald's theory has the beauty of simplicity. It explains why the tracheoesophageal fistula almost always involves the lower end of the esophagus, and why atresia is almost always accompanied by fistula. But it does not explain why fistula should not occur without atresia, and indeed one would expect that since the trachea is developed from the esophagus, congenital fistula between them would be common. If Gruenwald's theory is correct, there is nothing in it showing that fistula without other abnormality cannot occur.

If it be granted that on embryologic grounds, fistula without atresia can occur at least as readily as fistula with atresia then one asks why the condition is not met more frequently in clinical practice. There are three possible answers to this. First fistula with atresia was considered a rare condition until a surgical cure was devised, and simple diagnostic measures were widely published. Second, the simple diagnostic measures which prove the presence of fistula with atresia will not necessarily show the presence of a fistula only. Third the clinical features of fistula without atresia lack the dramatic quality of fistula with atresia, they do not necessarily suggest the diagnosis in themselves, and the onset of symptoms may be delayed until adult life. These latter points are brought out by a survey of the literature of cases of fistula only, and by the two new cases now recorded.

REVIEW OF LITERATURE

The literature of congenital abnormalities of the esophagus, including tracheoesophageal fistula, was extensively reviewed by Cautley[9] in 1917. A further review was made by Plass[10] in 1919, prompted by a case of fistula with atresia, and again more recently by Haight[11] in 1948, prompted by the discovery of two cases of fistula without atresia. Many of the cases here reviewed have been noted by one or the other, or all three, of these authors.

The first recorded case of fistula only is that of Richter,[12] in 1792. It was a peculiar abnormality in which the trachea and esophagus formed a single sac. This can be classified as a fistula in its most gross form, but otherwise has little similarity to the other cases. One can see, however, how such an abnormality might arise on the basis of Gruenwald's[4] theory.

In 1849, Vrolik[13] recorded a case, classified by Cautley[9] as one of fistula without atresia, but by Plass[10] as one of fistula with atresia. Unfortunately, the original paper is not available in this country.

Cautley[9] mentioned Von der Water[14] as recording the next case in 1857, but once again, the original reference is unobtainable.

In 1873, Lamb[15] recorded a case in an American journal. Haight[11] has verified this case, which, he stated, was of a patient who died at the age of 7 weeks. In the same year, 1873, Pinard[16] and Tarnier[17] independently recorded the same case, which Haight[11] has again verified, and which he stated was a high subglottic fistula, similar apparently to that successfully closed by Imperatori.[9] Pinard and Tarnier's patient died at 36 hours.

Eppinger[18] recorded a case of fistula, just above the carina, in a "young man" who died. Haight[11] has verified this case also, and it is the first case recorded in the literature, with reasonable certainty, of a congenital fistula being found in an adult. This was in 1880.

Heiderich,[19] at a demonstration of pathologic anatomy in 1916, showed a specimen of human thoracic viscera which showed a cord joining the esophagus to the right bronchus. The cord, which could be easily lifted out, and had no diseased lymph glands around it, started with a broad base in the esophagus, some of whose longitudinal fibers turned into it. The other end was attached to the posterior wall of the right bronchus some 2 cm. from the bifurcation. The esophagus, when opened, revealed a funnel shaped pouch corresponding to the place where the cord started. It slanted downward in a short canal which easily allowed a fine probe to pass, and followed the axis of the cord, finally opening into the right bronchus with a small round opening. Heiderich believed that this fistula was congenital. It would appear that the congenital origin was accepted in the discussion. In 1917, Cautley[9] made his extensive review, already mentioned. His paper consists of a classification of the recorded abnormalities of the esophagus, and included six cases of fistula without atresia, those of Richter,[12] Von der Water,[14] Lamb,[15] Pinard[16] and Tarnier,[17] Vrolik,[13] and Eppinger.[18]

In 1919, Plass[10] followed with a further review. His paper is of interest in that it quotes verbatim the first account, by Thomas Gibson in 1696, of a case of fistula with atresia. Plass quoted Lamb[15] as his only case of fistula without atresia. He did not include Eppinger[18] or Von der Water[14] in his review at all. He quoted Pinard[16] and Tarnier[17] as a case of fistula with atresia, but Haight,[11] as stated previously, has verified this case as one of fistula only.

In 1921 Widmann[20] gave a very full account of a post-mortem on a 34-year-old "Landstrumm" recruit, who died following an acute exacerbation of chest disease of fourteen years' duration. The terminal illness was in June 1918, characterized by fever, headache and bloody sputum. Death occurred in July, following a severe hemoptysis. Autopsy showed an old "obsolete" lesion at the left apex with caseous softening of the lymph glands at the hilus. There was old bronchiectasis of the left lower lobe with callous thickening of the stroma. The left lung was densely adherent. There were sanguinopurulent bronchitis and bronchopneumonia of the left lung. On the right side there were light adhesions. Finally there was a tracheoesophageal fistula situated on the posterior wall of the trachea, where it began as a funnel as thick as a pencil, diminishing to a few millimeters wide in the middle of the posterior wall at the level of the tenth cartilaginous ring. It passed steeply backward and downward through the anterior wall of the esophagus, entering the lumen 7.7 cm. below the interarytenoid indentation. The lining of the fistula was free from scarring, and admitted a 2 mm. probe throughout. There was no surrounding scarring or lymphadenitis. In the discussion which followed the presentation of this case, which was accepted as congenital, it was agreed that cases of fistula without constriction of the esophagus were rare. Stubler described one case and referred to three others, the patient in one of which survived seven weeks (possibly Lamb's case). The long survival in Widmann's case was attributed to the direction of the fistula downward from the trachea to the esophagus.

Although so few cases had been recorded up to that time, reference is made to the condition in two textbooks published in 1928 and 1929. Anders[21] stated: "In the adult tracheoesophageal fistulas, which can sometimes be very fine, can give passage to particles of food into the trachea and they can cause aspiration pneumonia or gangrene of lung." Jackson and Coates[22] stated: "Congenital fistulae are usually fatal; the patients who survive are those with only a small opening covered by a fold or a thin film of membrane. In one such patient who came to the Bronchoscopic Clinic the film had evidently given way two years before; fatal pulmonary complications had been prevented by feeding with a stomach tube."

In the same year 1929 Negus[23] showed to the Royal Society of Medicine a specimen of the esophagus of a man of 45 years who had died from carcinoma of the lung. There was a congenital opening passing downward from the trachea to the esophagus. At the esophageal end was a valvelike hood of mucous membrane. There had been no symptoms during life. "Negus has seen no other case of this condition and unfortunately the specimen was destroyed during the war."[24]

Clerf[25] reported, in 1933, a case of a woman of 23 years in whom a fistula between the esophagus and the left lower lobe bronchus was demonstrated by esophagoscopy, barium swallow and radiography following the passage of radiopaque bougies. The state of the lung is not recorded in any detail. The fistula was treated by cauterization with silver nitrate, and appeared to oblierate. The fistula was 29 cm. from the upper teeth at esophagoscopy. No opinion was given on the cause of this fistula, but the history was of seven years' coughing on swallowing. The patient's age at onset was thus 16 years, and since no other disease is mentioned, it is reasonable to assume a congenital origin. Late progress is not reported.

In the same year, McKinney[76] reported another case in the same journal. This was a woman of 58 years, with a history of recurrent attacks of vomiting for twenty-five years, and with recent attacks of coughing and spitting up food after meals. The fistula was shown by barium swallow, and confirmed by bronchoscopy when beads of pus could be seen passing through the fistula, which was itself too small to be seen. Esophagoscopy failed to show the fistula, too small to be found among the folds of mucosa. A further barium swallow confirmed the previous findings. McKinney reviewed the literature at the time, and considered that it was a congenital fistula occluded until middle life by a membrane. He reported a personal communication from Chevalier Jackson, in which Jackson stated that he had found a number of such fistulas in older children and adults.

Two, and possibly three, cases were reported in 1937. Moersch and Schmidt[77] reported two cases. The first was of a woman of 31 years, who gave a history of coughing up particles of food for eight years. A fistula passed from the lower esophagus to the right lower lobe bronchus. There was suppurative pneumonia of the right lower lobe. Death followed an operation, the details of which are not given. Autopsy showed no cause for the fistula, which was large. It was seen at esophagoscopy and bronchoscopy. Moersch and Schmidt's second case was of a man of 52 years, whose history was of strangulation and dyspnea on drinking, since childhood. Solids caused little distress. There had been four attacks of pneumonia in the left lower lobe. The fistula passed to the left lower lobe bronchus; it was seen at esophagoscopy, when the orifice was observed to open and close, and could easily have been missed if closed. The authors regarded their second case as congenital, the etiology of the first being in doubt.

In 1937 also, Tobias and Carlone[78] reported a case of "congenital esophagotracheal fistula in a man of 35, complicated by a gangrenous abscess of lung." This article is not available in this country.

In 1939, Imperatori[79] described a case of fistula in a boy of 6 years. The fistula was high, at the level of the third and fourth tracheal rings, and was repaired by a transcervical, transtracheal route. This case appears to be similar to that of Pinard[16] and Tarnier.[17]

In 1941, Gengenbach and Dobos[80] reported ten cases of fistula, the patients of seven of which had atresia. Of the remaining three, one was of fistula without any other abnormality of the esophagus, and was proved at autopsy in a child of 3 months. The fistula was 4 mm. in diameter, and passed downward from the trachea to the esophagus, entering the trachea 3 mm. above the carina. The second case was of a child of 10 months, diagnosed by bronchoscopy. There was some obstruction or stenosis of the esophagus This child was alive at the time of the report The third case was suspected the diagnosis not being proved at the time of the report

In 1945, Leven and Lannin[31] discussed cases of fistula with atresia and in the course of the article mentioned two cases of fistula without atresia These cases were found in the records of the Department of Pathology of the University of Minnesota, between 1916 and 1938 No details are given

Haight,[11] in 1948 recorded a case in a child of 4 years There had been choking on feeding since birth and soon after birth fistula with atresia was suspected The esophagus was shown to be patent by barium swallow, on the fourth day of life The barium swallow did not outline the fistula Attacks of pneumonitis persisted, and the diagnosis was made at the age of 3 years, by Lipiodol swallow in the prone position Bronchoscopy showed the fistula 1 5 to 2 cm above the carina, in the right posterolateral wall of the trachea The fistula was 4 mm in diameter, at its narrowest Haight successfully closed the fistula by an extrapleural paravertebral approach Haight had previously seen a similar case, which he had reported in a paper on fistula with atresia [32] and which is also described in Patten s textbook of embryology [33] The radiologic features of fistula with atresia were dealt with by Haight and others in a further paper [34] He pointed out that the usual procedure for establishing the diagnosis of fistula with atresia namely to instill a little Lipiodol into the upper esophagus through a fine catheter will not outline a fistula if the esophagus is patent The oil will run into the stomach and will pass through the fistula into the trachea only if it is instilled into the esophagus in the prone position In his paper[32] Haight stated that he is aware of two other cases of fistula only which do not appear to be reported in the literature

To retain the chronological order of this review of case reports my own first case must be mentioned at this point This case was diagnosed and treatment was made in 1948, and it was reported to the Society of Thoracic Surgeons of Great Britain in 1949 Details are given in the case reports in the following section

Morton, Osborne, and Klassen recorded a case in 1950 [35] The patient was a man of 26 years, in whom a congenital fistula passed from the esophagus downward to the right lower lobe bronchus The symptoms of coughing of ingested food particles did not arise until adult life He was successfully treated by right lower lobectomy and closure of the fistula

Berman Test and McArt[36] reported a case in 1952 of a woman of 40 years in whom the fistula passed from the esophagus to the left lower lobe bronchus Symptoms had been present from birth She was treated by left pneumonectomy and closure of the fistula There were associated vascular abnormalities in this case A patent ductus arteriosus was present in the usual position and there was a second ductus, arising from the aorta and communicating with the basal branch of the pulmonary artery This suggests that the developmental error may have been of a different kind from that postulated for these cases and possibly of the kind which gives rise to sequestration of lung a condition described by Pryce, Sellors, and Blair[37] and now familiar to most thoracic surgeons. Berman, Test, and McArt mentioned four cases of fistula without atresia, of congenital origin, in their article,[36] of which two are not included in this review. These are recorded by Walters[38] and Berglund.[39]

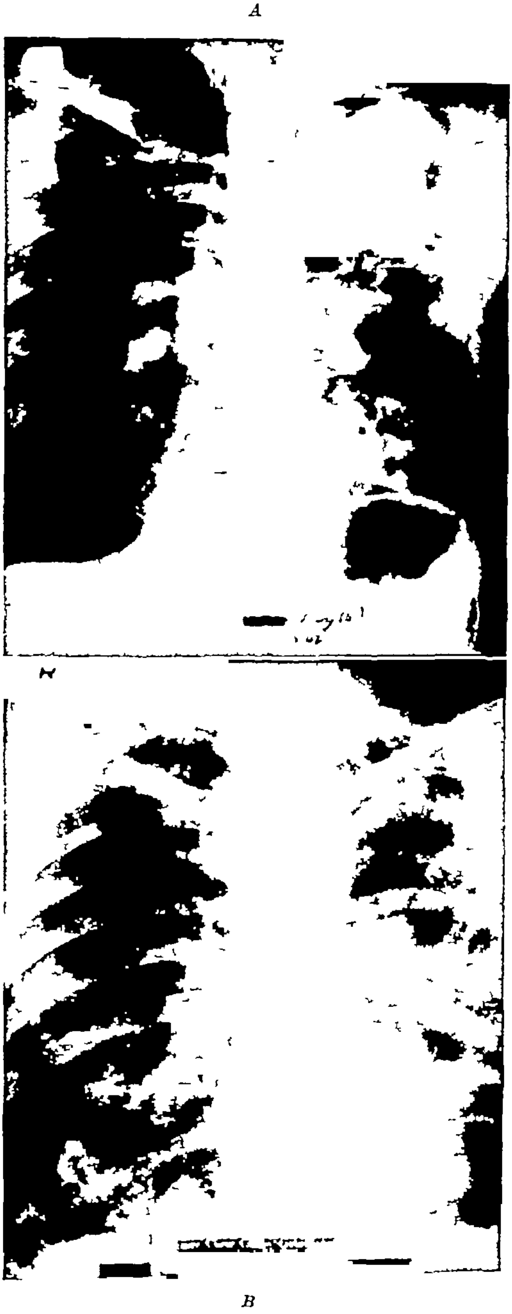

Fig. 4.—Case 1. Radiographs showing pneumonitis in the left lung in 1942 (*A*) and 1948 (*B*). In the later film there is a well-marked cavity in the left lower lobe and a pneumonitis in the right mid zone.

A further case has recently been recorded by Krause[41] in 1953 in an African woman of 38 years The fistula was very large 4 4 by 1 9 cm and death resulted from asphyxia following impaction in the fistula of a bolus of meat

There are thus some thirty cases of congenital esophagotracheal or esophagobronchial fistula recorded in the literature about equally divided between adults and children Three of these have been treated by transthoracic operation To this list I am able to add two further cases

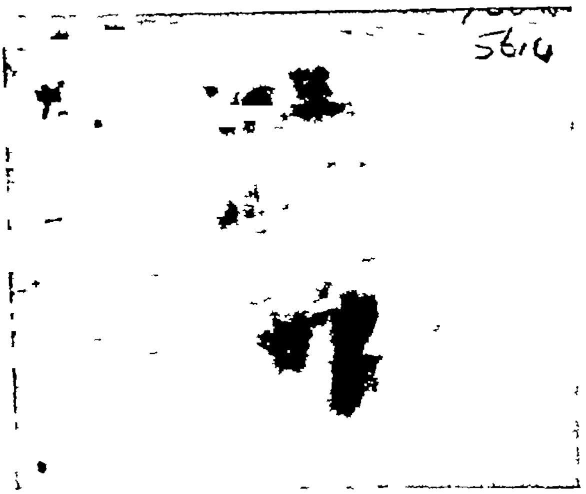

Fig 5—Case 1 A barium swallow showing barium entering the left main bronchus

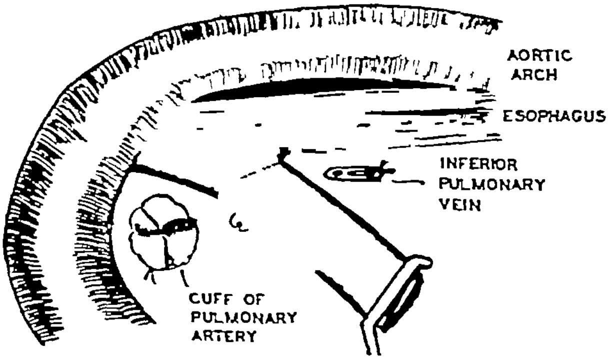

Fig 6—Case 1 Drawing of appearances after pneumonectomy The bronchial stump has been left long and is being used to draw the fistula from beneath the aortic arch. The subsequent line of section of the bronchus is shown dotted

CASE REPORTS

Case 1—A 54 year old man had a history of cough with purulent sputum for eleven years and of coughing of ingested food particles for six months He had been investigated in many hospitals and had been in a sanatorium for three months No tubercle bacilli had ever been found in the sputum Two years previously a bronchogram had suggested the presence of a fistula but esophagoscopy and bronchoscopy had failed to reveal it A survey of the radiographs taken over many years showed a chronic infective process in the left lung mainly in the lower lobe, in which there was a cavity (Fig 4) There had been many exacerbations and remissions of the infective process, but the right side had suffered only a transient pneumonitis in 1948 The development of the pathognomic symptoms of coughing

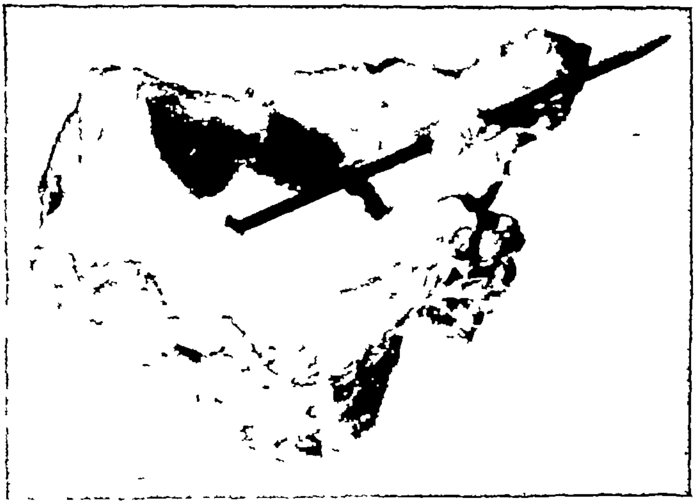

Fig 7—Case 1 The segment of the left main bronchus showing the fistula

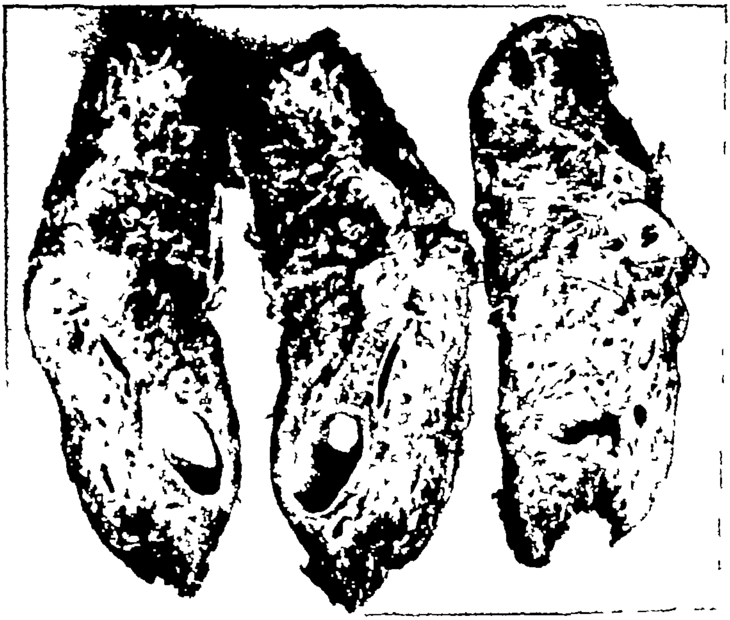

Fig 8—Case 1 Sections of the resected left lung

of ingested food particles, symptoms which had not been present two years previously when a fistula had been suspected on a bronchogram at a previous investigation in another unit now left the diagnosis in little doubt A barium swallow showed the fistula, passing from the esophagus to the left main bronchus (Fig 5) The mouth of the fistula could not be seen at esophagoscopy and was only found with difficulty at bronchoscopy This was because of the extremely small bronchial mouth, situated in the depression between two cartilaginous rings A probe could just be passed into it

On June 17 1948 left pneumonectomy and closure of the fistula were carried out The chest was opened through the bed of the resected sixth left rib the patient being in the prone position described by Parry Brown [40] The lung was densely adherent to the chest wall and diaphragm but the hilum and mediastinum were not involved in this fibrosis Dissection pneumonectomy was performed leaving the stump of the bronchus long to act as a tractor to draw the carina and fistula from beneath the aortic arch. This was done with surprising ease, and the fistula displayed with a minimum of blunt dissection. (Fig 6) The fistula entered the posterolateral wall of the left main bronchus 1 5 cm below the carina at the junction of the cartilaginous and posterior membranous portions of the wall of the bronchus It was 2.3 mm. outside diameter at the point of entry into the bronchus and about 1 cm. in length. Funnel shaped it widened rapidly so that it was 0 75 cm diameter at its entry into the esophagus and about 1 cm. in length The bronchus was clamped above the fistula and divided The fistula was divided at its entry into the esophagus and the segment of bronchus with the fistula was removed (Fig 7) The defect in the esophagus was closed with a few interrupted linen thread sutures and the bronchus closed with interrupted linen thread and covered with a pedicled intercostal muscle graft The chest was closed without drainage The patient made a good recovery and returned to work but in February 1949 eight months after operation he made a violent effort to lift a heavy weight, and felt a sharp pain in the chest Within twenty four hours he was admitted to the hospital with fever and a profuse productive cough He had in fact developed a virulent empyema due to rupture of the bronchus stump The empyema was drained and he left the hospital to return within a few days after a severe hemorrhage from the empyema drainage tube Hemorrhages of increasing severity recurred during the following few days,

Fig 9—Case 2 A barium swallow showing the fistula passing to the right dorsal lobe bronchus

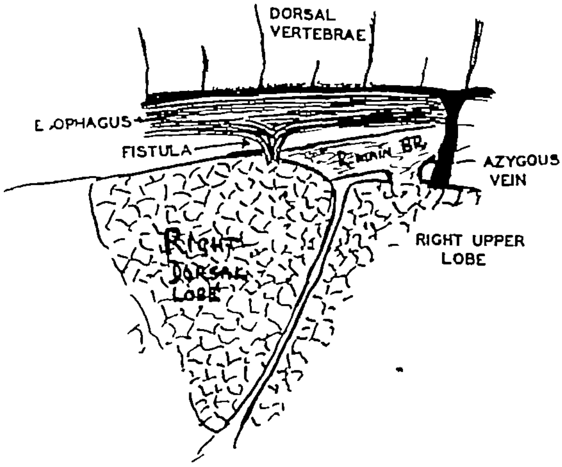

Fig 10 —Case 2 Diagram of appearances at operation

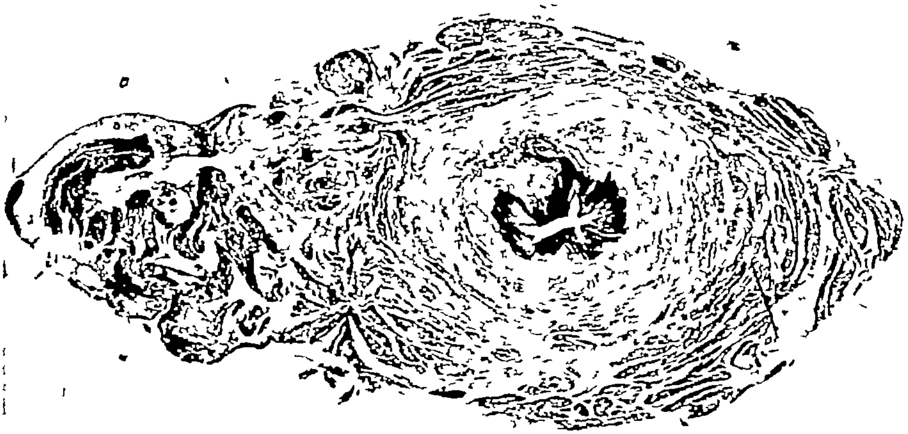

Fig 11 —Case 2 A photomicrograph of a cross section of the fistula, showing a muscular wall and a squamous epithelial lining

and the chest was reopened in order to control the hemorrhage As soon as this was done a torrential hemorrhage took place, and he died within a few seconds Post mortem showed that the hemorrhage was due to rupture of an infective aneurysm of the descending arch of the aorta This had converted the pneumonectomy space into a false aneurysmal sac The post mortem showed no evidence of disease which might have caused the broncho esophageal fistula Examination of the resected left lung had shown only chronic nonspecific inflammatory changes, with no evidence of tuberculosis, actinomycosis, or neoplasm (Fig 8)

CASE 2.—A 54-year old woman gave a history of enlargement of the thyroid gland for two to three years, one year before coming to the hospital, she had noticed a bad taste in the mouth, and for five months she had suffered from regurgitation of fluids from the esophagus, which had become worse in the previous two months. There was no clear cut history of coughing on swallowing The symptoms were attributed to the enlarged thyroid and thyroidectomy was carried out uneventfully, but without relief of symptoms A barium swallow was carried out, and this revealed a fistula passing from the esophagus to the right dorsal lobe bronchus (Fig 9) She was then referred to the Thoracic Unit Esophagoscopy showed a suggestion of the fistula 27 cm from the upper incisor teeth, a dimple in the mucosa At bronchoscopy, there was likewise a suggestion of a fistula in the floor of a *groove in the* posterior wall of the right main bronchus, just above the dorsal lobe orifice Except for the unequivocal demonstration of the fistula by barium swallow, its presence would not have been suspected at these endoscopies On Jan 23, 1953, a right thoracotomy was performed with the patient in the prone position The dorsal lobe had a well marked fissure separating it from the basal segments, and there were filmy adhesions over the dorsal lobe The fistula could be seen through the *mediastinal* pleura There was no inflammatory reaction around it, and it was picked up and dissected out without difficulty It arose from the lateral aspect of the esophagus, and ran at right angles to it, to enter the medial side of the dorsal lobe bronchus just distal to its origin from the main bronchus It was funnel shaped, about 2 cm in length, 1 cm. broad at the esophageal attachment, and 0 5 cm broad at its bronchial attachment (Fig 10) It was ligated at its bronchial attachment, and divided The esophageal attachment was divided, and the esophageal defect closed with a few interrupted linen thread sutures The chest was closed without drainage The patient made an uneventful recovery, with complete relief of symptoms The fistula, after excision, easily admitted a probe, it was lined with squamous epithelium (Fig 11)

DISCUSSION

Of the thirty odd cases now reported, no clinical details whatever are available for six of them[12 14 19 31] In another nine only the age at diagnosis or death is known, of these nine, four patients died within a few days of birth[11 15 1-] another died at age 3 months[30], two cases were diagnosed during the first year and the patients were living when the cases were reported[30] and the other two were adults one a "young man,"[15] the other aged 35 years[28] Fifteen cases remain concerning which clinical details are known One patient died aged 2 or 3 days of pneumonia[11] another was aged 23 months, and had lung symptoms[15] a third had recurrent attacks of pneumonitis and was successfully operated upon at the age of 4 years, by Haight[11] A fourth had an unusual type of fistula high in the subglottic region and a difficult history of regurgitation, complicated by a history of pyloric stenosis This fistula was successfully closed by Imperatori[22] in a boy of 6 years

Haight has given a very full account of the clinical aspects of the condition in childhood and infancy and the present discussion will be confined to the remaining eleven cases in which the abnormality was first diagnosed in adult life and in which there is available an adequate record of the case history The striking fact immediately emerges from these eleven case histories that in only two of them did symptoms date from birth or early childhood One patient had no symptoms referable to the fistula, in the other eight, symptoms first occurred in adult life Furthermore, symptoms of coughing of ingested food were present from the onset in only five of the eleven, and were not found at all in two These facts are shown diagrammatically in Fig 12 This is important, because it leads to difficulty in diagnosis in the early stages, when the patient presents with recurrent or chronic attacks of pneumonitis, unless a fistula is suspected, it is very unlikely to be found accidentally, and even if suspected, proof of its presence is not easy to find since the very small orifices of the fistula in bronchus and esophagus make it very difficult to see them, even when their approximate location is known, and when diligent search is being made, also esophagoscopy

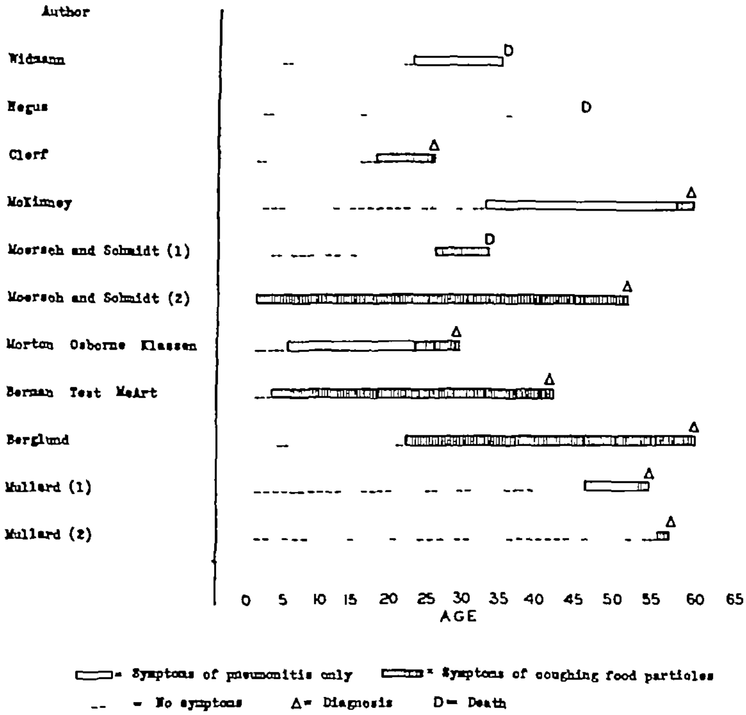

Fig 12 —Diagram showing age at onset and duration of principal symptoms in adult patients

does not often form part of the investigation of cases of recurrent pneumonitis The key investigation is an opaque swallow, using either a thin barium mixture or Lipiodol Swallows should also be carried out in the prone position so that gravity can assist the opaque material to flow forward into the trachea or bronchus Although it is improbable that these fistulas are at all common, it may well be that they are a good deal more common than the published reports suggest, and it may be advisable to include an opaque swallow in the investigation of cases of pneumonitis which are recurrent or refractory to treatment

Many of the fistulas described, including the one in my Case 1, have passed from the esophagus to the trachea above the carina It would be possible to carry out lobectomy and even pneumonectomy without discovering the presence of the fistula, which in these cases lies entirely within the upper mediastinum in an area undisturbed during pulmonary resection If resection of a destroyed lobe or lung were carried out in the presence of such a fistula which remained undetected then one would anticipate progressive infection in the residual lobe or in the contralateral lung It may be that this is the explanation of some of those cases of progressive pulmonary suppuration following resection which occur occasionally in the practice of most thoracic surgical units

The reasons for the late onset of symptoms in general and of the pathognomic symptoms in particular are worth consideration Jackson and Coates[22] considered that the fistula is occluded by a fold or membrane which breaks down in later life While this is possible there has been no evidence of such a membrane in my cases in both of which the fistula has been lined with squamous epithelium continuous from esophagus to bronchus The esophageal mucosa is normally mobile within the muscular coat, and moves downward with the bolus on deglutition But the mucosa is firmly attached to the fistula, and this will cause a fold of mucosa to develop and override the orifice of the fistula as the bolus passes giving some protection against entry of food particles into the fistula This mechanism will also account for the difficulty of seeing the orifice of the fistula at esophagoscopy But there is no reason why this mechanism should fail in course of time

Another possibility is that the direction of the fistula upward or downward from the esophagus accounts for the variation in the time of onset of symptoms from one case to another There is insufficient evidence in the case reports to support this theory

It may be that the explanation of the late onset of symptoms in many cases is that the normal mobility of the esophagus in relation to the other mediastinal contents, and especially the bronchi is interfered with by the progressive adherence of the affected lung to the chest wall and mediastinal pleura Adhesions form, and become increasingly dense, with each of the recurrent attacks of pneumonitis Eventually the affected lobe or lung will become firmly adherent to the chest wall and mediastinal pleura The esophagus normally descends on deglutition and the esophageal mucosa descends in relation to the muscular coats When the lung becomes fixed the free descent of the esophagus will be restricted at least at the point of attachment of the fistula The tendency may well be that the fistula is pulled open by this means while at an earlier stage, when there was free movement of the lung bronchus and fistula as well as esophagus descended together the mouth of the fistula being occluded by a fold of esophageal mucosa during the passage of the bolus as described previously

SUMMARY

The embryology of congenital tracheoesophageal fistula with and without atresia of the esophagus is reviewed

The published reports of congenital fistula without atresia are summarized Two new cases of this condition are reported, both diagnosed during life and treated by direct transthoracic approach

The clinical history and symptoms of cases of fistula without atresia, with special reference to the condition in adult life, are discussed

Attention is drawn to the late onset of symptoms in most cases, and especially to the late onset of pathognomic symptoms and also to the difficulties of diagnosis

A theory is advanced to account for the late onset of symptoms

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POSTINFLAMMATORY "TUMORS" OF THE LUNG

REPORT OF FOUR CASES SIMULATING XANTHOMA FIBROMA OR PLASMA CELL TUMOR

W O UMIKER, COMMANDER (MC) USN * AND LALLA IVERSON M D **
ST ALBANS, N Y AND WASHINGTON D C

INTRODUCTION

IT IS the purpose of this paper to present four cases with pulmonary lesions characterized by mild or no symptoms roentgenographic pattern of a single sharply circumscribed mass suggesting tuberculoma or neoplasm histologic features of fibroma neurofibroma xanthoma or plasma cell tumor and historical evidence of an antecedent respiratory infection

Brown and Johnson[1] recently reported three such tumorlike lesions of the pleura which they regarded as consequences of inflammation They stated that similar masses of inflammatory origin had been found within the lung

REPORT OF CASES

CASE 1†—A 24 year old white man was being examined prior to separation from the Navy when a small intrathoracic mass was seen in roentgenograms of the chest (Fig 1) Roentgenograms taken four months earlier had been negative but for the previous two months he had had a slight cough productive of small quantities of yellow sputum Extensive bacteriologic and cytologic studies did not reveal the cause of the lesion, which was tentatively diagnosed "pulmonary tuberculoma" Right upper lobectomy was performed.

A well-circumscribed soft spherical nodule 3 cm in diameter was found 2 cm. beneath the pleura The central cystic space was surrounded by a friable granular yellowish brown wall Microscopic sections of the mass showed bundles of interlacing spindle shaped cells with relatively abundant acidophilic cytoplasm and large nuclei (Fig 2) The nuclei were rather variable in size and shape and some were moderately bizarre yet no mitotic figures were found In other areas numerous macrophages were roughly polyhedral with round or oval nuclei (Fig 3) Some contained brownish pigment that stained positively for iron Clusters of foam cells containing sudanophilic fatty material were a striking feature especially near foci of hemorrhage (Fig 4) Scattered throughout were varying numbers of chronic inflammatory cells mostly plasma cells, with fewer lymphocytes and neutrophilic polymorphonuclear leukocytes (Fig 5) The adjacent pulmonary parenchyma was the site of recent hemorrhage

CASE 2‡—A 5½ year old white girl became ill, in February 1937 with moderately productive cough fever nausea and vomiting sore throat and cervical lymphadenopathy The acute symptoms subsided in five days leaving some weakness slight clubbing of the fingers and daily elevation of temperature Roentgenograms one month later revealed a large annular mass in the right lung (Fig 6) Three months following the onset of illness a right upper lobectomy was performed

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AFIP Acc No 170825 contributed by the late Dr H. Brunn San Francisco California

The well circumscribed, soft, spherical mass was 5 cm in diameter The cut surface was pink tan and somewhat gelatinous, with areas of hemorrhage and strands of fibrous connective tissue Microscopic sections showed the "tumor" to be partly composed of spindle cells, associated with a loose diffuse network of adult fibrous connective tissue

Fig 1

Fig 2

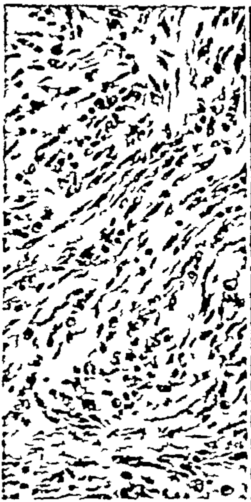
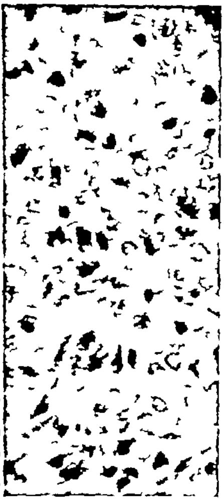


Fig 3



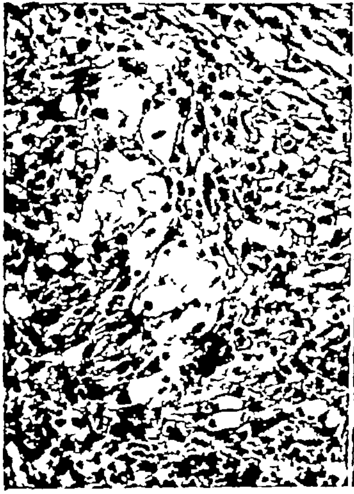


Fig 4

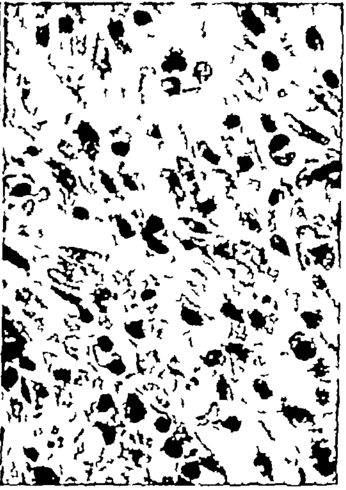


Fig 5

Fig 1 —Case 1 Roentgenogram of the chest showing a sharply circumscribed mass in the right upper lobe.

Fig 2 —Case 1 The tumor is composed of interlacing bundles of spindle cells with scattered plasma cells and lymphocytes (X250)

Fig 3 —Case 1 Macrophages and scattered small inflammatory cells (X475)

Fig 4 —Case 1 Aggregates of foam cells as seen here are not uncommon (X425)

Fig 5 —Case 1 Plump spindle cells and plasma cells are hall marks of this inflammatory tumor (X635)

The bulk of the mass was composed of plasma cells, mononuclear cells, and lymphocytes (Figs 7 and 8) No mitotic figures were seen The patient was living and well seven years after operation, and there had been no x ray evidence of recurrence

Case 3* —A 35 year-old white woman with a history of repeated attacks of bronchitis complained of vague pain in the chest for seventeen months On roentgenographic examination in 1943 she was found to have a radiopaque shadow in the left lung which was tentatively diagnosed as tuberculoma Roentgenograms taken regularly during the following years showed the mass unchanged except for more obvious circumscription It was removed by lingulectomy at the end of six years

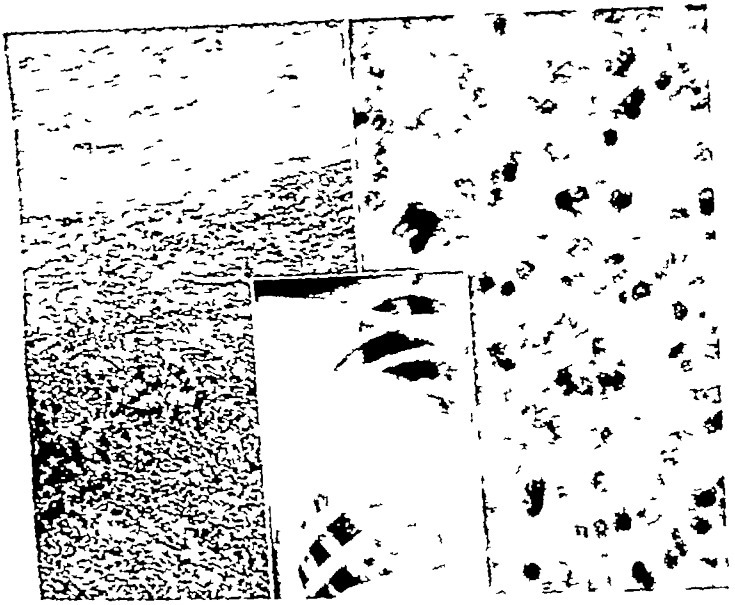


Fig 7 Fig 6 Fig 8

Fig 6 —Case 2 Roentgenogram of the chest showing a large mass involving the right lung

Fig 7 —Case 2 The fibrous capsule surrounding a dense accumulation of cells many of which are plasmacytes (X75)

Fig 8 —Case 2 Spindle and polyhedral cells are interspersed with plasma cells some of which are binucleated. (X555)

The encapsulated nodule was 2.5 cm in diameter (Fig 9) Its cut surface was smooth and golden yellow, with several hemorrhagic and firm translucent foci Microscopic examination revealed a thin fibrous capsule enclosing a mass composed of bundles of spindle cells that appeared to be laying down collagenous connective tissue (Fig 10) The bulk of the tumor consisted of large macrophages with foamy or granular cytoplasm (Fig 11) Although the nuclei of the spindle cells were somewhat variable in appearance there were no mitotic figures Scattered plasma cells were observed (Fig 12) Focal hemorrhages were present and aggregates of lymphocytes were seen at the periphery

Case 4† —A 41 year-old white man had lobar pneumonia in 1928 when he was 19 years old followed by a persistent cough productive of brownish sputum The respiratory symptoms continued for twenty years In 1948 he was thought to have an adenoma of the bronchus of the lower lobe of the right lung The obstructing mass was removed bronchoscopically with temporary relief of symptoms Bronchoscopic examination in 1950 twenty two years after the initial illness disclosed a mass obstructing the middle and lower main bronchi on the right Lobectomy was performed shortly thereafter

The encapsulated spherical mass measured 7 cm in diameter The cut surface bulged and was light yellowish gray with small yellow flecks Microscopic examination showed interlacing bundles of spindle cells and hyalinized fibrous connective tissue Although these cells varied in size and shape and possessed atypical nuclei, no mitotic figures were seen (Fig 13) Interspersed among these elements were scattered plasma cells and lymphocytes in varying numbers (Fig 14) Nests of foam cells were present The adjacent lung tissue exhibited some fibrosis pigmented macrophages and a few lymphocytes In the year that elapsed after operation there was no evidence of recurrence

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*AFIP Acc No 258217 contributed by Dr Thomas Peery Washington D C reported by Ford Thompson and Bland 43

†AFIP Acc No 455798 contributed by Dr C Allen Payne Grand Rapids Michigan.

Fig 9

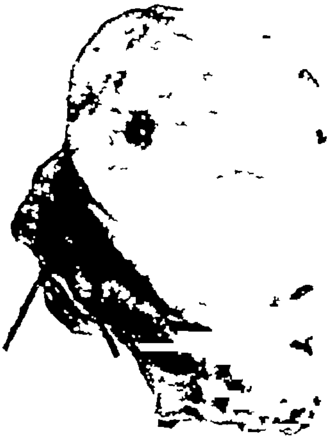
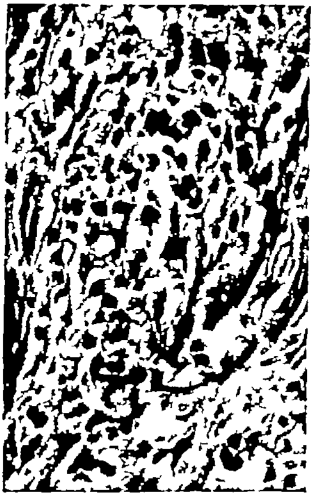


Fig 10



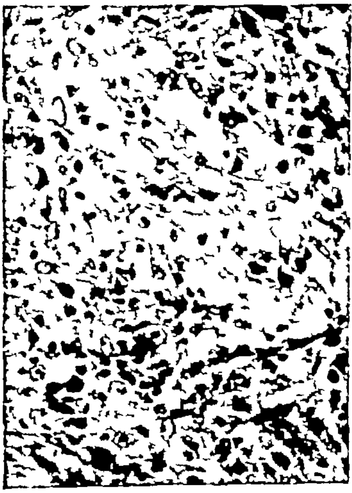


Fig 11

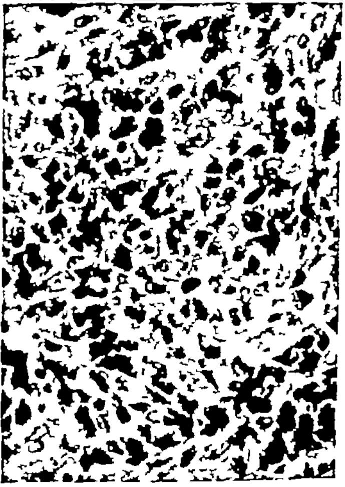


Fig 12

Fig 9 —Case 3 This well encapsulated mass was golden yellow A hemorrhagic focus is seen on the left side. (×3)

Fig 10 —Case 3 Hyalinized fibrous connective tissue fibers and scattered inflammatory cells most of which are plasma cells. (×435)

Fig 11 —Case 3 Foam cells containing fat contributed to the yellow color of this tumor" Spindle polyhedral and scattered inflammatory cells are also seen (×355)

Fig 12 —Case 3 This area of the 'tumor contains numerous plasma cells (×435)

TABLE I. SUMMARY OF CLINICAL AND PATHOLOGIC FEATURES OF SEVEN INFLAMMATORY TUMORS OF LUNG

	AUTHOR	SEX AGE	LOCATION OF MASS	CHIEF SYMPTOM	PAST HISTORY	CLINICAL DIAGNOSIS	GROSS APPEARANCE	MICROSCOPIC FEATURES
1	Case 1 (AFIP 530833)	M 24	PUL	Cough	Chronic cough for 2 months before removal of mass	Tuberculosis	Circumscribed soft spherical mass 3 cm. diameter Cut surface yellow Central cavity	Fibroblasts foam cells plasma cells hemorrhages No mitoses
2	Bruno 1939 (AFIP 170825)	F 5½	RUL	Cough Fever	Onset with febrile respiratory infection	Tuberculosis	Circumscribed soft spherical mass 5 cm. diameter Cut surface pink tan	Plasma and other inflammatory cells fibroblasts hemorrhages No mitoses
3	Ford and associates 1950 (AFIP 280217)	F 35	LLL	Chest pain	Repeated attacks of bronchitis	Tuberculosis	Circumscribed spherical mass 2 5 cm diameter Cut surface yellow	Fibroblasts, hyalinized fibrous connective tissue foam cells plasma cells No mitoses
4	Case 4 (AFIP 485708	M 41	RLL	Cough	Lobar pneumonia at 19 years bronchial adenoma removed at 39 yr	Tumor	Circumscribed firm spherical mass 7 cm. diameter Cut surface yellowish gray	Fibroblasts collagenous fibrous connective tissue, foam cells plasma cells hemorrhages No mitoses
5	Childress and Adie 1950	M 21	RML	Cough	Chronic cough 8 months	Tumor	Circumscribed firm spherical mass 4 cm. diameter Cut surface yellow gray	Plasma and reticulum cells eosinophils dense collagenous connective tissue foam cells in adjacent alveoli
6	Csernely 1941	M	PUL	?	‹ Fibroma of lung removed 7 years previously		Circumscribed firm spherical mass replacing entire lobe	Fibroblasts hyalinized fibrous connective tissue foam cells No mitoses
7	Scott and associates 1948	F 24	RUL	Hemoptysis	Pleurisy 11 years before operation	Tuberculosis	Circumscribed friable spherical mass 4 5 cm diameter Cut surface yellow	Fibroblasts hyalinized fibrous connective tissue foam cells hemorrhages No mitoses

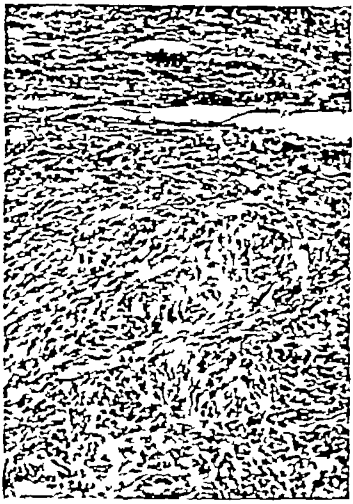


Fig 13

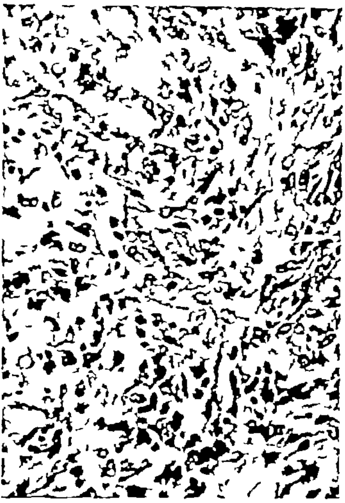


Fig 14

Fig 13.—Case 4. Atypical fibroblasts and inflammatory cells compose the tumor (×235.)

Fig 14.—Case 4. Scattered plasma cells and lymphocytes among connective tissue elements (×235.)

DISCUSSION

Two of the four cases described have been reported elsewhere,[2, 3] and a search of the medical literature for other examples yielded three additional cases.[4-6] With the increasing frequency of surgical removal of circumscribed pulmonary masses, whether neoplastic or inflammatory, it may be anticipated that these supposedly rare lesions will be discovered in greater numbers.

The clinical and pathologic features of the seven cases are charted in Table I. It is readily seen that all of the lesions were similar in that they tended to have a prolonged course, showed no progressive increase in roentgenographic size, were well circumscribed, and were characterized histologically by fibroblastic and endothelial organization of the diseased area, with varying admixtures of inflammatory cells. Of particular significance were the results of surgical removal for extirpation of the tumor was completely successful. These tumorlike masses were unrelated to age. The youngest patient was 5½ years and the oldest, 41 years of age. Both sexes were affected. The majority of patients gave a history of respiratory tract infection preceding discovery of the intrathoracic mass. The infection was usually in the form of pneumonia, pleurisy, or recurrent bronchitis. In Cases 2 and 4, the patients had a definite history of pneumonia preceding the appearance of the mass, and in Case 1, a negative x-ray film was recorded four months before the mass was discovered, with a respiratory infection in the interim. Hence it seems justifiable to relate the mass to the antecedent infection.

The presenting symptoms were characteristically mild. Most of the patients had only moderate cough, which was nonproductive or slightly productive of mucopurulent sputum. Only one patient had chest pain. Laboratory studies were uniformly within normal limits and in no instance were pathogenic organisms recovered from sputum or gastric washings

The roentgenographic appearance of these masses was not diagnostic Most of the "tumors" were peripherally located, and only one was on the left side The upper lobe was affected with approximately the same frequency as the lower The lesions appeared as opaque sharply circumscribed spherical masses with or without central cavitation The combination of a history of pleurisy, cough or hemoptysis with the roentgenographic appearance described usually resulted in a clinical diagnosis of pulmonary tuberculosis and the discovery of "tumor" at operation or autopsy was usually unexpected

Pathologic Features—Grossly all the lesions were sharply circumscribed, spherical nodules from 2 5 to 7 0 cm in diameter The degree of encapsulation varied The consistency of the mass depended upon the relative proportions of its components Thus lesions which were chiefly xanthomatous were soft and friable, those with a preponderance of plasma cells were moderately firm and granular and those with dense fibrosis were rubbery Two of the lesions were distinguished by central cavity formation but there appeared to be no significant relationship with the bronchi None of the nodules was directly in contact with pleura

Microscopically the most characteristic feature was the combination of several components These were (1) spindle-shaped cells (2) vascular fibrous connective tissue with or without hyalinizing fibrosis, (3) foam cells with sudanophilic material, and (4) chronic inflammatory cells chiefly plasmacytes

The spindle shaped cells tended to be arranged in interlacing bundles, which although characteristic of leiomyoma or neurofibroma were less well organized than those found in muscle or nerve sheath tumors These cells had abundant pink staining cytoplasm with vesicular or hyperchromatic nuclei, which often exhibited considerable variation in size and shape Nevertheless, mitotic figures were absent These spindle shaped cells were interpreted as fibroblasts There appeared to be transition forms between these fibroblasts and the less numerous macrophages Some of the latter contained brown pigment which was readily identified as hemosiderin The amount of collagen appeared to vary with the age of the process Varying numbers of adult fibrocytes were present In several instances the predominance of fibrous components led to an initial diagnosis of fibroma In one lesion vascularity was such a prominent feature (Case 1) that the possibility of a vascular tumor had to be excluded

Foam cells containing sudanophilic material when present were often interspersed with fibroblasts thus giving an appearance of "xanthofibroma" when these cells predominated Cases 3 and 4 were both reported as "xanthoma In this group the banal inflammatory cell constituents were less conspicuous the connective element well defined and the macrophages with foamy or granular cytoplasm abundant

Plasma cells were seen in varying number in all the lesions They were so numerous in Case 2 that the lesion was originally interpreted as a plasma cell tumor or plasma cell granuloma, although Brunn[2] referred to it as an unusual benign tumor of "contradictory pathology." Lymphocytes and other *inflammatory cells were present in smaller numbers*, connective tissue elements were fewer, and foam cells were absent.

The lung parenchyma adjacent to the "tumors" usually was not remarkable. Recent hemorrhage, possibly resulting from the surgical procedure, was commonly described immediately around the mass, and areas of fibrosis accompanied by macrophages were sometimes noted.

Diagnostic Considerations.—The clinical features, such as antecedent respiratory infection, long duration without change in roentgenographic size of the mass, absence of recurrence following surgical removal, together with morphologic aspects, including circumscription of the mass, inflammatory features, fibrosis, and lack of mitosis, support the interpretation that these lesions are the result of antecedent infection and are not neoplasms. Although in some instances it was impossible to determine whether an infection actually preceded the tumor, in Cases 1, 2, and 4 the evidence that the fibroblasts and capillaries were part of a hyperplastic repair process, rather than a neoplasm, appeared to be unequivocal.

It is apparent from a review of the literature and a study of the four cases reported herein that these lesions are usually interpreted as neoplasms when a particular cell dominates the histologic picture. This is true of the xanthofibroma reported by Csermely[5] in 1941, and of a similar lesion included in this series. If the fibroblasts or their cellular products form the bulk of the mass, the tumor, of course, resembles a fibroma. Similarly, when plasma cells predominate, the tumor may be classified as a "plasma cell tumor" or "plasma cell granuloma."

The microscopic appearance of the tumors further supports the theory of their inflammatory origin. First, even when one cell type predominates, such as the fibroblast or plasma cell, the cells are sufficiently uniform and regular in appearance that one would hesitate to associate them with neoplasia unless misled by the unusually circumscribed and firm, gross character of the tumor. Moreover, the admixture of other cells, such as lymphocytes and lipoid macrophages, and the free intermingling of all of these histologic elements are other traditional features of chronic inflammation and repair and are not uncommonly found in chronic inflammatory lesions of the lung, such as unresolved pneumonia or an organizing abscess. Finally, fragments of elastic fibers may be demonstrated throughout the inflammatory "tumor," in contrast to their arrangement in true neoplasms in which similar elastic remnants are seen only at the extreme periphery, where replacement of the lung parenchyma is still incomplete.[2]

We are of the opinion that all these "tumors" represent variants of a postinflammatory repair process and are similar to the tumorlike pleural masses reported by Brown and Johnson.[1] Therefore, they may be referred to as inflammatory pseudotumors and are to be carefully differentiated, both clinically and histologically, from true neoplasms, especially sarcomas.[7]

SUMMARY

1 Four postinflammatory "tumors" of the lung are described and compared with three similar ones from the literature

2 Clinically, the lesions are characterized by a history of infection of the upper or lower respiratory tract and roentgenograms suggestive of tuberculomas or well-circumscribed neoplasms

3 Morphologically, they closely simulate true tumors, such as xanthoma, xanthofibroma, neurofibroma, fibroma, vascular tumor or plasma cell tumor

4 The most important anatomic criteria which should arouse suspicion of postinflammatory "tumors" are generous numbers of inflammatory cells within the mass maturity of the fibroblastic components lack of mitotic activity and remnants of pre existing parenchyma throughout the mass in the form of elastic fibers

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CILIATED EPITHELIAL CYST OF THE ESOPHAGUS ASSOCIATED WITH CARDIAC ABNORMALITIES

Report of Two Cases

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CILIATED epithelial cysts of the mediastinum comprise an interesting group of congenital anomalies which are being encountered with increasing frequency. The commonest type is found in the region of the tracheal bifurcation or main stem bronchi. Because these are thought to be derived from a pinching off of a bud from the primitive trachea, they are called bronchogenic cysts. The second, less common type of ciliated epithelial cyst, which occurs in the wall of or adjacent to the esophagus, has been variously labeled "esophageal," "foregut," or "ciliated epithelial esophageal" cyst.

Characteristically located in the lower third of the esophagus, these cysts usually project to the right. Histologically, they are composed of a lining epithelium of pseudostratified, columnar, ciliated cells resting on a layer of submucous connective tissue, which may contain scattered tubular glandular formations and some smooth muscle. Stratified squamous epithelium may also be present in some areas. Since many of the esophageal cysts are intramural, the wall generally contains, in addition, muscle fibers which are derived from the esophageal muscular coats. Plates of hyaline cartilage are occasionally found within the walls of the cysts. The lumen is filled with a grayish-white viscid fluid resembling boiled starch. There is no communication with the lumen of the esophagus.

The first report of an esophageal cyst is credited to Wyss,[21] who, in 1870 described a tumor in the posterior wall of the esophagus, 3.8 cm. above the gastric cardia; the lining of the cyst was lost. In 1913 Pappenheimer[16] collected from the literature 14 cases of ciliated esophageal cyst and added 2 of his own, and in 1944 Ranstrom[18] reported 17 cases. A recent review of the literature has disclosed 16 other cases,[2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 17, 20, 22] making a total of 49 reported cases.

Reports of cardiac symptoms associated with mediastinal tumors are extremely rare. In 1931 Sauerbruch[20] removed an epithelial cyst from the lower third of the esophagus of a 13-year-old boy who was suffering from dyspnea, cardiospasm, and extreme cardiac irregularity. Following removal of the cyst, these symptoms disappeared. Rawls and Ancona[19] reported a case of malignant lymphoma that appeared as a small nodular mass in the left mediastinum near the pulmonary hilum. The patient had paroxysmal auricular fibrillation, which disappeared after the tumor responded favorably to radiotherapy.

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Similarly, Adamson[1] recorded a case of mediastinal tumor associated with sinus arrhythmia, nodal premature beats and pulsus paradoxus. At necropsy a lymphosarcoma was found attached to the posterior surface of the sternum and involving the posterior wall of the pericardium. Donovan[9] described a case of severe angina pectoris that persisted for eight days and terminated fatally. Necropsy revealed coronary sclerosis with complete occlusion of the right coronary artery and a leiomyoma in the lower third of the esophagus. Because severe thoracic pain of such long duration is uncommon in myocardial infarction, Donovan concluded that the esophageal tumor may have been a contributing factor.

Recently, we operated upon two patients with circumscribed mediastinal tumors lying between the esophagus and heart, both of which proved to be ciliated epithelial esophageal cysts. Both of these individuals had cardiac abnormalities; in one, regression of cardiac symptoms following surgical removal of the cyst suggested a causal relationship. Because of the rarity of such association, the two cases will be described in detail.

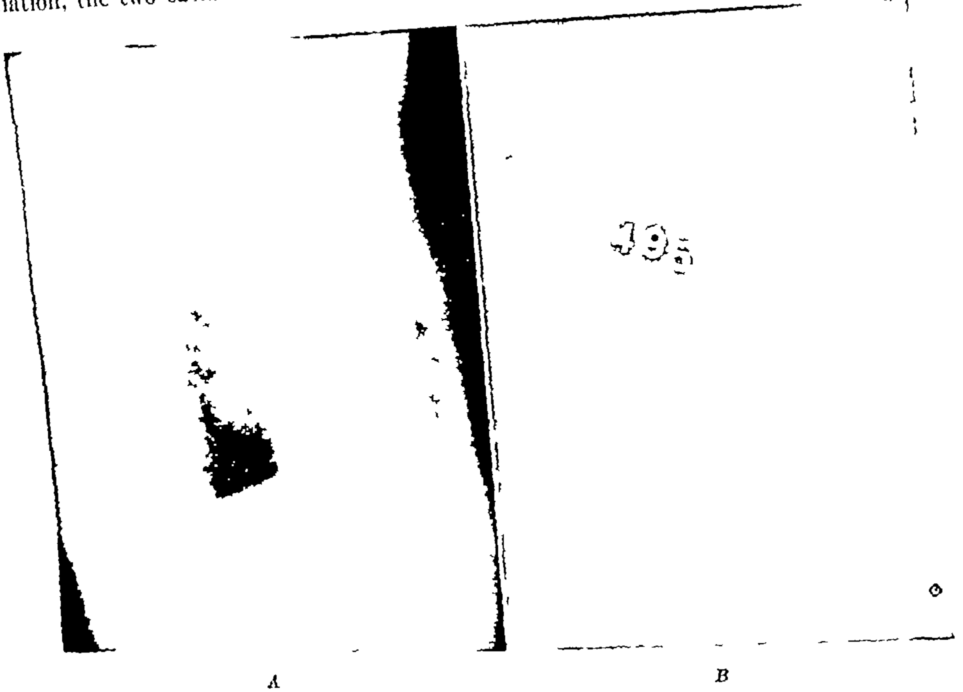

Fig. 1.—Case 1. *A*, Oblique and *B*, lateral roentgenograms of the chest showing a posterior mediastinal density at the level of the ninth thoracic vertebra.

REPORT OF CASES

Case 1.—C. D., a 48 year old white man, was admitted to the hospital on March 8, 1951, for investigation of a mediastinal tumor situated between the esophagus and the heart. A mediastinal shadow was discovered during roentgenologic examination of the upper gastrointestinal tract, which disclosed the presence of a prepyloric ulcer crater.

Physical examination failed to reveal any abnormality except frequent premature cardiac beats. Roentgenographic examination of the chest demonstrated a rounded, sharply circumscribed mass about 6 cm. in diameter along the posterior cardiac border in the region

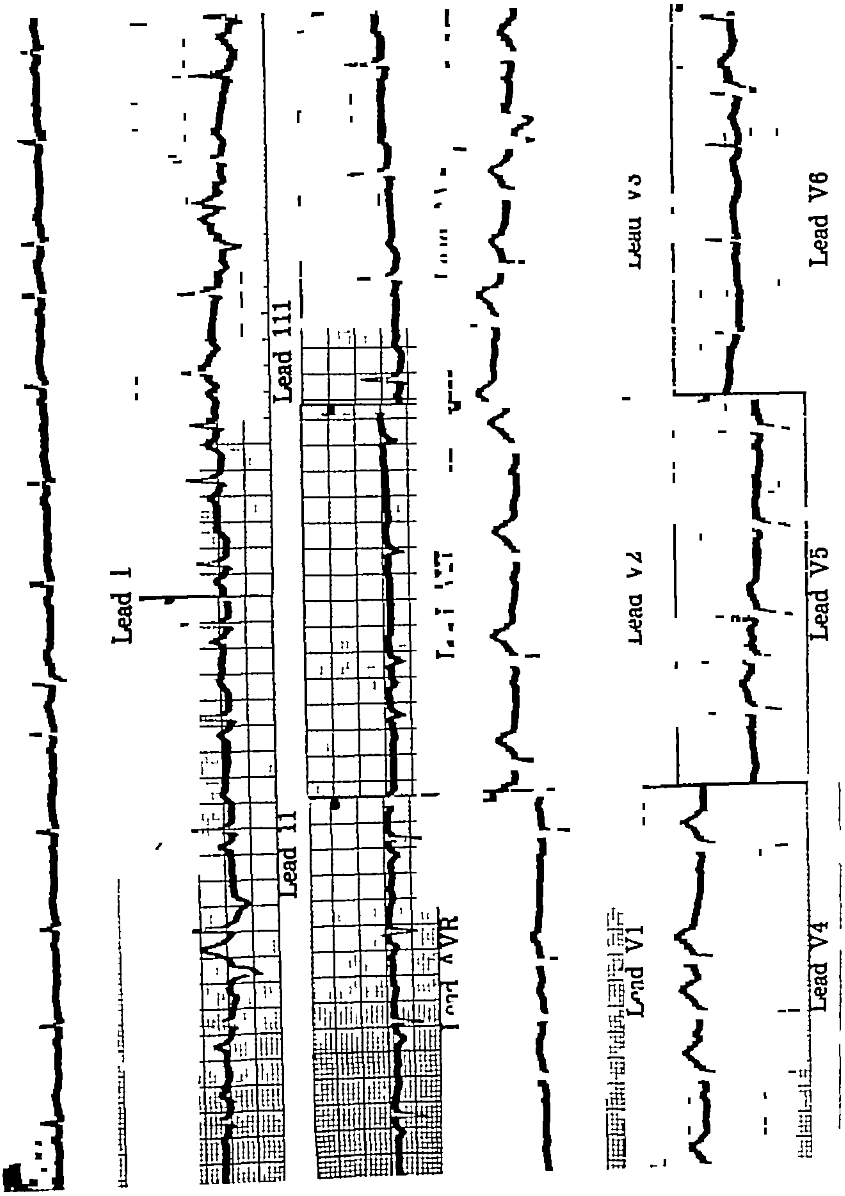

Fig 2A.—Case 1 Electrocardiograms taken preoperatively showing auricular and ventricular premature beats

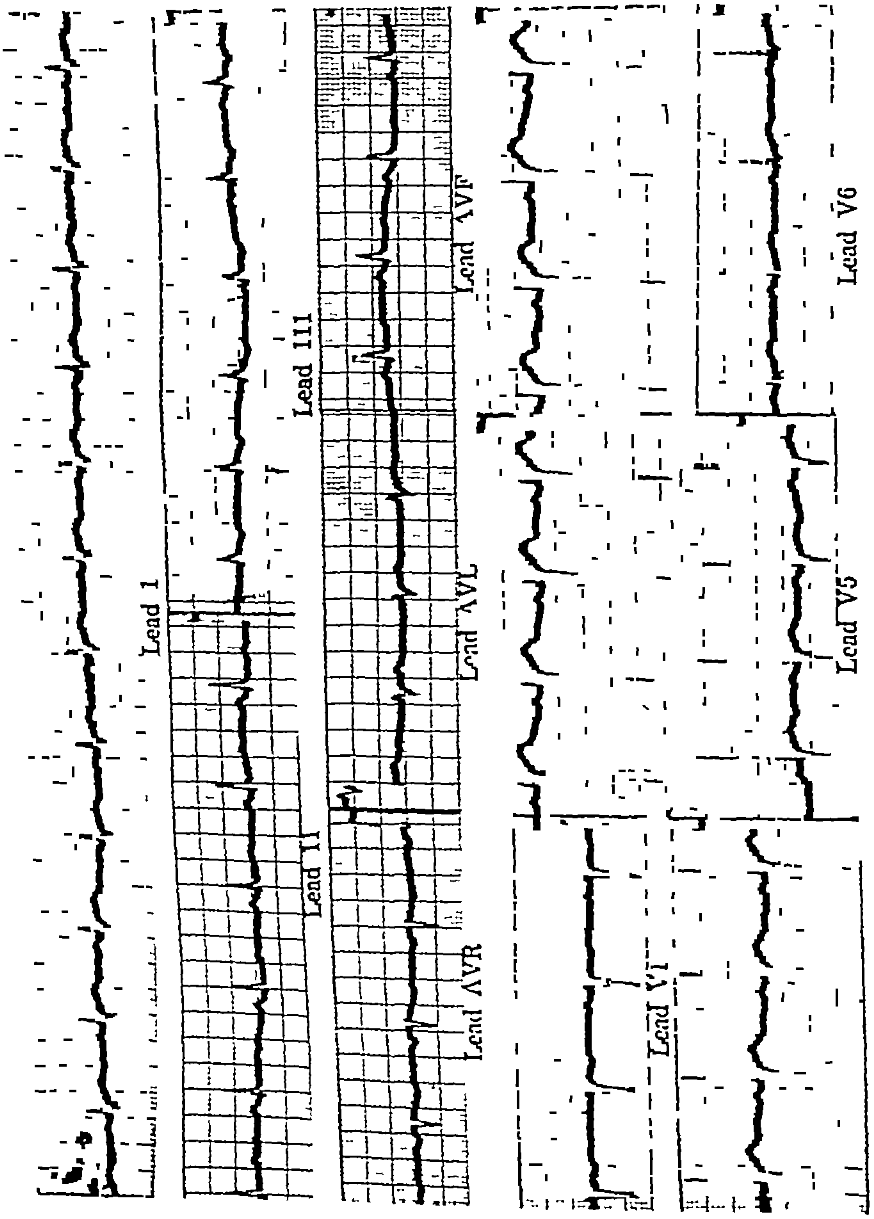

Fig 2B —Electrocardiograms taken postoperatively showing normal rhythm

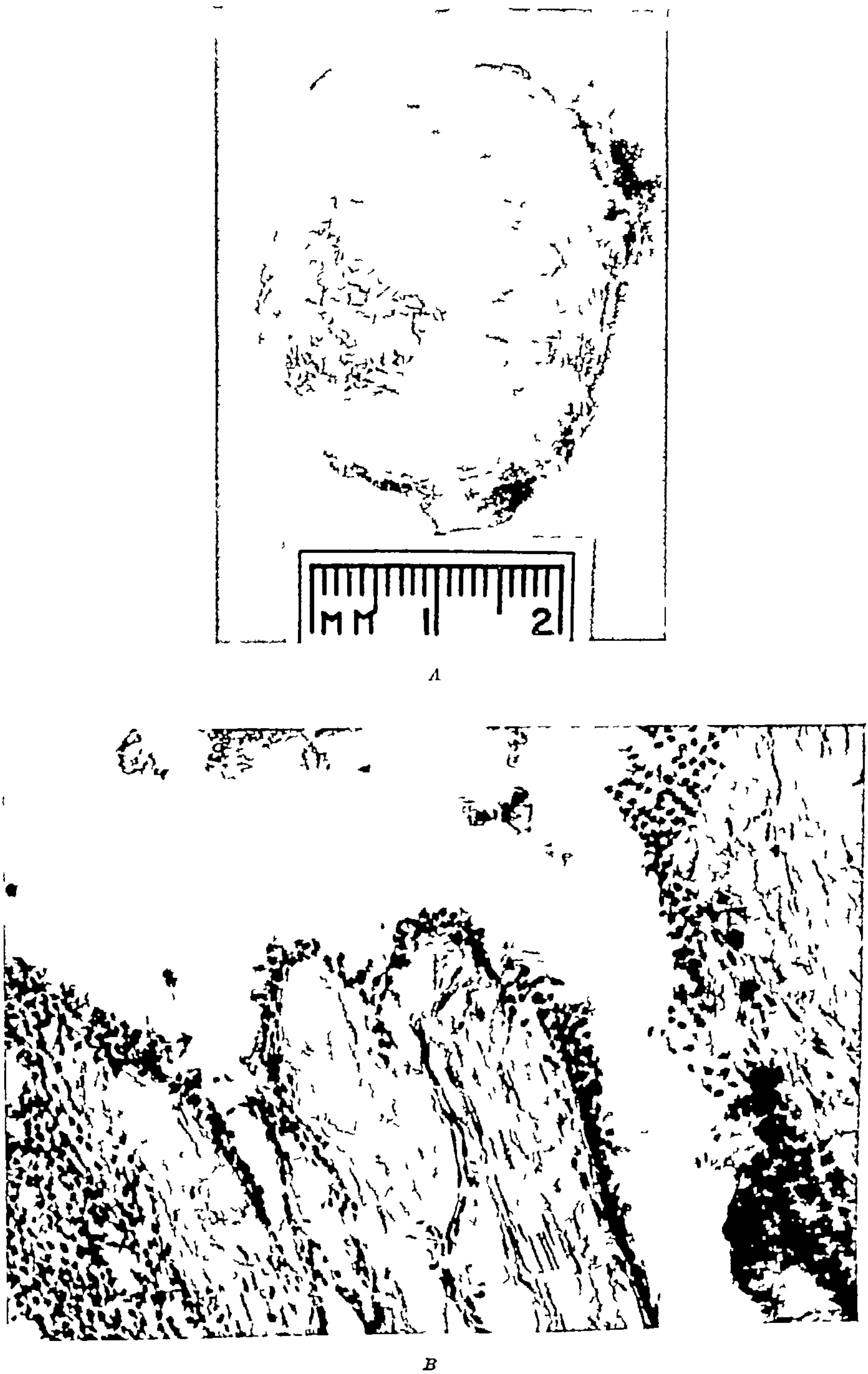

Fig 3—Case 1 *A*, Photograph of specimen and *B*, photomicrograph, showing pseudostratified epithelium which is ciliated in places

Fig. 4.—Case 2. A, Lateral roentgenogram of chest, showing posterior mediastinal density at the level of the ninth thoracic vertebra. B, Posteroanterior roentgenogram of barium-filled esophagus showing indentation of left anterior wall by the tumor.

of the right auricle and apparently contiguous to the heart (Fig 1) On fluoroscopy, the mass moved with cardiac contractions and, with barium in the esophagus, displaced the esophagus to the left, indenting its right anterior wall An electrocardiogram at that time showed frequent auricular and ventricular premature beats and S T segments suggestive of myocardial disease (Fig 2*A*)

On March 13, 1951, exploratory thoracotomy was carried out through a right posterior lateral incision, the chest being entered through the bed of the seventh rib Retraction of the lung anteriorly revealed a rounded mass within the mediastinum between the heart and esophagus at the level of the ninth thoracic vertebra. The mediastinal pleura over the mass was incised, and, on dissection, the cyst was found to be adherent to the pericardium over the right atrium but lying within the esophageal wall Mobilization of the cyst necessitated opening of the pericardium The esophageal musculature was incised, and the cyst was removed by blunt and sharp dissection, there being no communication with the lumen of the esophagus The esophageal musculature was then reapproximated, and the incision was closed.

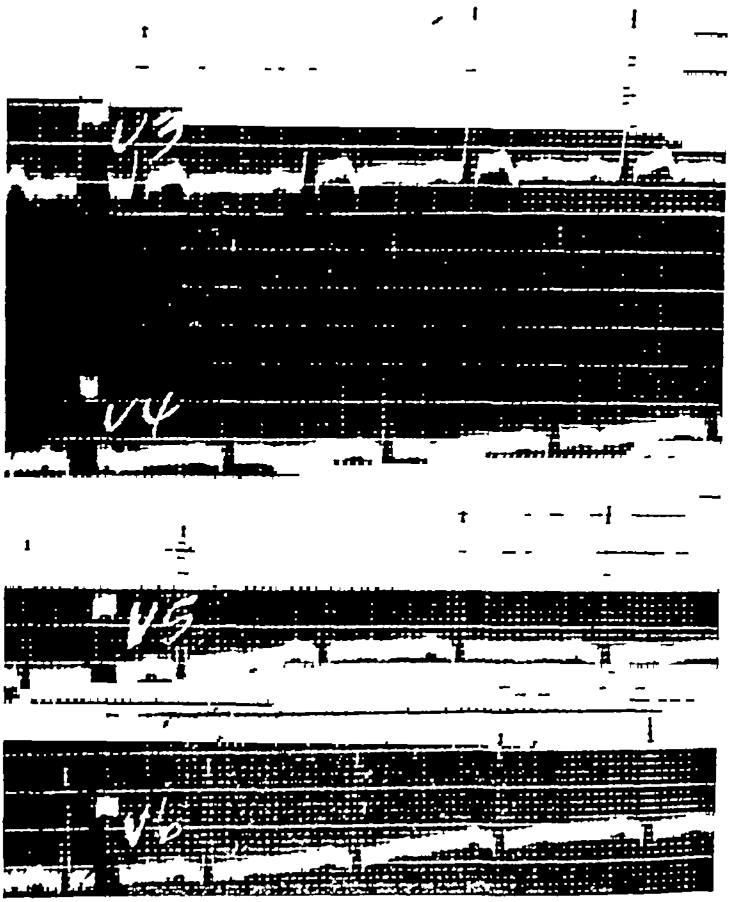

Fig 5—Case 2 Electrocardiogram taken before operation showing T wave changes in Leads V_3 V_4 and V_5

Postoperatively, the cardiac rhythm became regular (Fig 2*B*) Convalescence was uneventful, and the patient was discharged on March 20, 1951 When last seen twenty five months after operation, he had no cardiac symptoms except for occasional episodes of paroxysmal tachycardia.

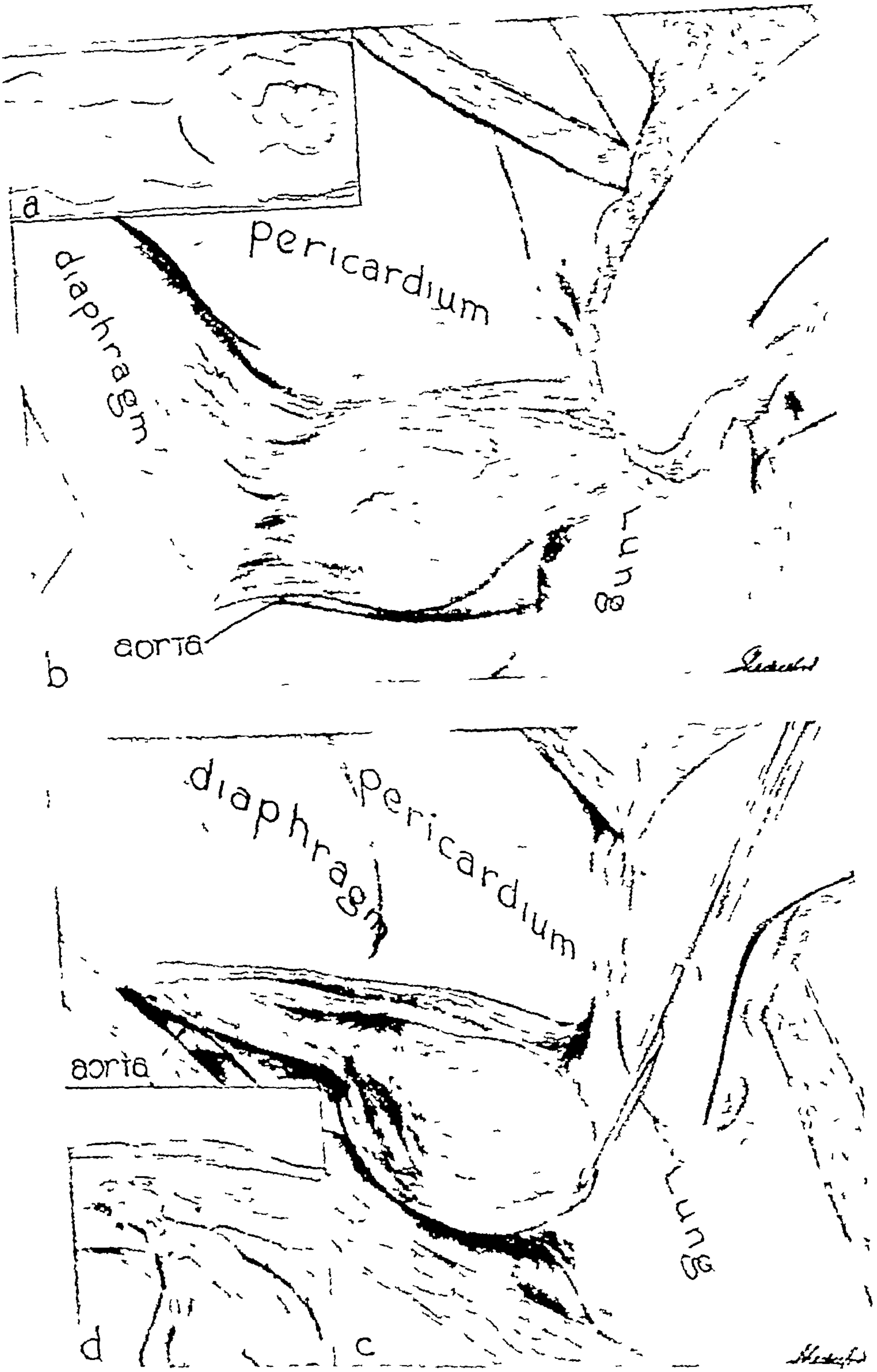

Fig. 6.—Case 2. *a*, The left posterior lateral incision. *b*, Relation of cyst to heart, diaphragm and pulmonary root. *c*, Extension of longitudinal muscle fibers over cyst indicating its intramural location. *d*, Cyst being separated from submucosa.

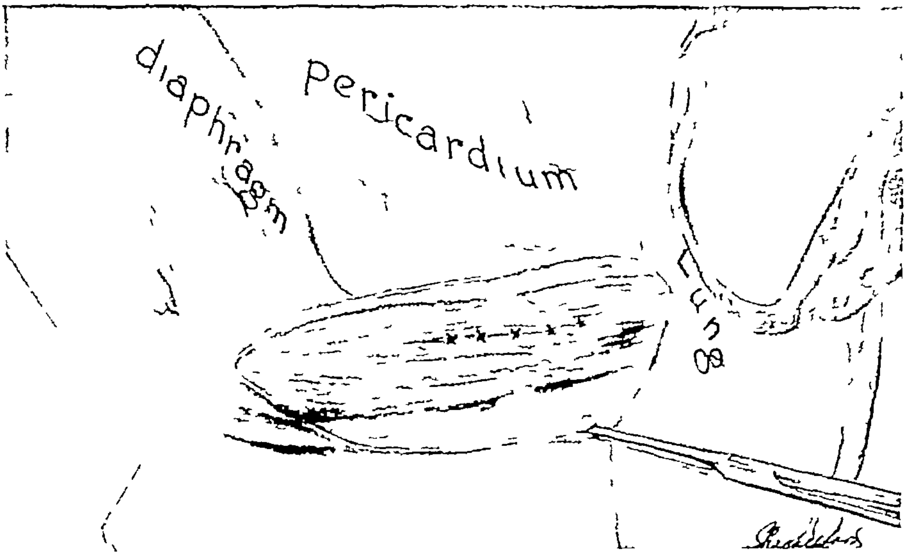

Fig 7.—Case 2 Reapproximation of esophageal musculature with interrupted silk sutures

Fig 8.—Case 2 Photograph of gross specimen.

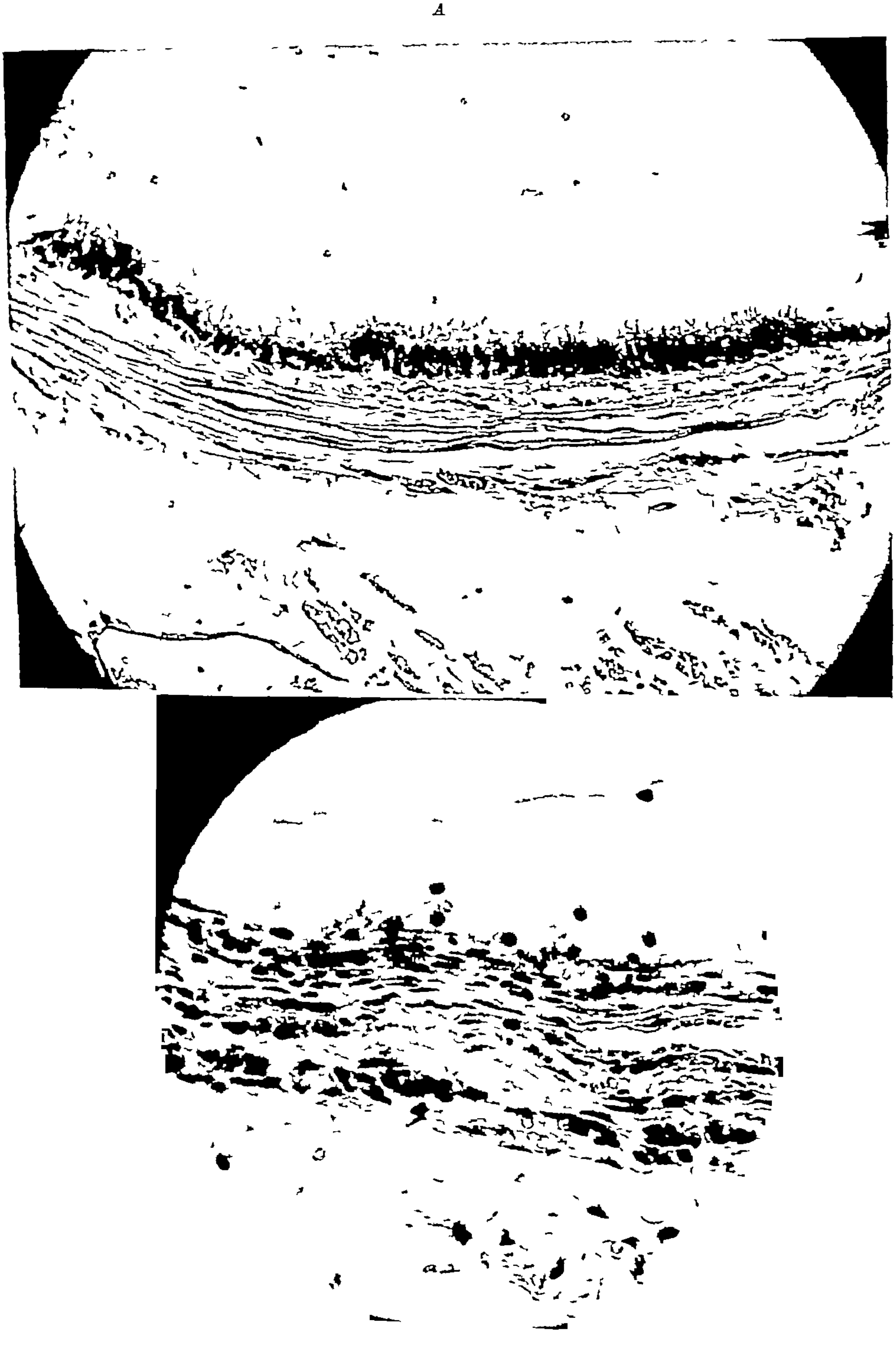

Fig. 9.—Case 2. Photomicrographs showing *A*, ciliated pseudostratified lining epithelium and *B*, hyaline cartilage in wall of cyst.

Pathologic report Grossly, the cyst was oval and approximately 6 cm in its long axis Its external surface was wrinkled and grayish yellow (Fig 3, *A*), its lining smooth in parts and rough and papillary in others It contained viscid, dull white material. The wall of the cyst, which varied from 1 to 4 mm. in thickness, revealed microscopically a moderate amount of smooth muscle fibers running in a longitudinal and an oblique direction. A moderate amount of edematous stroma was present The inner lining consisted primarily of a single layer of compressed epithelial cells, although in a few areas definite pseudostratified columnar ciliated epithelial cells could be seen (Fig 3, *B*) The pathologic diagnosis was developmental cyst of esophageal origin.

CASE 2—M D, a 30 year old white man, was admitted to the hospital on March 4, 1953, for investigation of a retrocardiac mediastinal tumor discovered on routine roentgenography of the chest Upon close questioning, the patient admitted having rather mild pains in the retrosternal area which radiated to both pulmonary fields

Physical examination revealed no abnormalities except a Grade II aortic systolic murmur Roentgenograms of the chest exhibited an oval density lying behind the heart and to the left of the midline at the level of the ninth thoracic vertebra (Fig 4, *A*) Fluoroscopic examination of the esophagus following ingestion of barium showed indentation of its left anterior wall by the mediastinal tumor (Fig 4, *B*) An electrocardiogram revealed T wave changes in Leads V_3, V_4, and V_5 indicative of myocardial disease (Fig 5) The esophagus appeared normal on esophagoscopy

A preoperative diagnosis of esophageal cyst was made, and, on April 2, 1953, exploratory thoracotomy was carried out through a posterior lateral incision, the chest being entered through the bed of the left seventh rib Exploration revealed a cystic mass within the posterior inferior mediastinum extending from the left inferior pulmonary vein to within 2 to 3 cm. of the cardia (Fig 6) The pulmonary ligament was divided, and the mediastinal pleura was reflected The cyst lay within the wall of the esophagus and was intimately attached to the pericardium over the left atrium. By its projection to the left, it was snugly interposed between descending aorta and heart The cyst was removed, along with the muscle fibers adherent to its outer surface, no communication with the esophageal lumen being found The esophageal musculature was then reapproximated (Fig 7), and the thoracic incision was closed Convalescence was uneventful, and the patient was discharged on April 8, 1953 An electrocardiogram taken three weeks postoperatively indicated improvement in the abnormality previously noted, however, the aortic systolic murmur remained unchanged

Pathologic report Grossly, the specimen appeared gray brown in color, measured 6 by 4 by 4 cm., and had a smooth, glistening external surface (Fig 8) The wall of the cyst measured 0 1 cm in thickness, and was of even width, it consisted microscopically of dense hyalinized fibrous connective tissue that was acellular in places The lining epithelium was composed partially of flat cuboidal cells and partially of pseudostratified ciliated cells In some sections hyaline cartilage was present in the wall of the cyst (Fig 9) The lumen was filled with a homogenous gray gelatinous substance The pathologic diagnosis was ciliated epithelial mediastinal cyst

DISCUSSION

Several theories have been advanced concerning the genesis of these mediastinal cysts According to Bremer,[4] gastrointestinal cysts arise as diverticula from the primitive gut during the 20 mm stage of the embryo These outpouchings of epithelium may come to lie in the submucosa, between the muscle coats, or outside the gut wall and, when separated from the lumen, become cysts Others are of the opinion that these anomalies represent congenital tracheo esophageal fistulas that have become occluded anteriorly and posteriorly Maier[13] has labeled all ciliated epithelial mediastinal cysts as bronchogenic, although he admits that some of the esophageal cysts may have a separate origin. Ranstrom[18] reported two cases of esophageal cysts, each of which contained a muscularis mucosae beneath the ciliated epithelial lining. Since the trachea has no muscularis mucosae, he concluded that these cysts must have originated in the esophagus.

The similarity in histologic structure of esophageal and bronchogenic cysts indicates a common origin. The fact that both trachea and esophagus arise from a common anlage, the primitive pharynx or tracheogular primordium, suggests that these two types of cysts have at least a common time, if not a common site, of origin. It is probable that at about the time of separation of trachea and esophagus (4 to 5 mm. stage) tissue fragments are sequestrated which contain either multipotential cells or both entodermal and mesodermal components. At this stage both esophagus and trachea are lined with ciliated epithelium. Fragments near or attached to the trachea remain associated with the tracheobronchial tree and comprise the bronchogenic group of cysts, whereas other sequestrated groups of cells in the wall of or near the esophagus become esophageal cysts. The rapid elongation of the esophagus which occurs at the time of descent of the heart, accounts for the development of many of the cysts in the lower third of its length.

The anomalies which have been described are not to be confused with the enterogenous or gastrogenous cysts occasionally found in the mediastinum, often attached to the esophagus. These cysts generally contain all the normal structural elements of the stomach or intestinal tract, including a functioning lining epithelium. Bremer[4] referred to these anomalies as duplications rather than diverticula.

Ciliated epithelial cysts, whether bronchogenic or esophageal, appear to be slowly growing tumors which, in the absence of infection, rarely produce symptoms. Most of those reported have been discovered incidentally either at necropsy or during routine roentgenographic examination of the chest. Bronchogenic cysts located about the tracheal bifurcation, particularly in the subcarinal region, may produce severe respiratory symptoms in the child, and cysts in the esophageal wall may cause partial obstruction of that organ.

Even in the absence of symptoms, surgical exploration is indicated for lesions presumed to be mediastinal cysts, since a definite diagnosis is impossible by other means. The treatment of choice is primary excision of the cyst, which has proved both safe and practical. Sauerbruch,[20] in 1931, was perhaps the first to perform primary removal of an esophageal cyst. Prior to that time, the few patients operated upon were treated by marsupialization of the cyst, with removal subsequently. Frequently, both longitudinal and circular muscle layers must be divided in order to expose the cysts, if they lie in the submucosa. Occasionally, the muscle fibers overlying the cyst must be excised if they are adherent. As these lesions do not communicate with the esophageal lumen, they can usually be removed without disturbing the mucosa.

It is interesting to speculate on the possible relationship between the retrocardiac esophageal cysts and the cardiac abnormalities in the two cases herein reported In the first (C D) the tumor lay behind the right atrium and from this position may have compressed the regions of both the sinoauricular node lying at the junction of the superior vena cava and the right atrium and the auriculoventricular node at the base of the interauricular septum Conceivably, this pressure from the cyst may have set up aberrant stimuli which resulted in the premature beats On the other hand, it has been demonstrated that cardiac contractions may be initiated from any section of the heart The irregularity of cardiac rhythm may have arisen, then, from an area of the auricular and ventricular wall in contact with the cyst and not from the nodal area It should be pointed out, however, that there is hardly more than suggestive evidence of a causal relationship between this cyst and the cardiac abnormality The etiology of premature beats is not always apparent, and the cause for their disappearance may be equally obscure, so that a causative role cannot be assigned to any single factor unless the evidence is definite

In the second case (M J), the preoperative electrocardiogram was abnormal, and although postoperative tracings showed some improvement, there is no real evidence that removal of the cyst was responsible for this, since bed rest alone may result in disappearance of this type of electrocardiographic abnormality Further follow-up studies are needed to establish definitely the relationship of the mediastinal tumor to the cardiac abnormality

SUMMARY

Ciliated epithelial cysts of the esophagus, though comparatively rare, are being recognized with increasing frequency Reports of 49 cases have been found in the literature Even rarer are reports of cardiac symptoms associated with mediastinal tumors We were able to find only 4 such cases in the literature

Two cases of ciliated epithelial esophageal cysts with associated cardiac abnormalities treated surgically are presented The anatomic proximity of the cysts to the heart and the electrocardiographic reversion toward normal, following excision of the cysts, suggest an etiologic role of mediastinal tumors in the production of cardiac abnormalities

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BILATERAL INTRATHORACIC NEUROFIBROMAS OF THE VAGUS NERVES

WITH A NOTE ON THE PHYSIOLOGIC EFFECTS OF CERVICOTHORACIC VAGECTOMY IN MAN. A CASE REPORT

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BILATERAL neurofibroma of the vagus nerves unassociated with generalized neurofibromatosis appears to be an uncommon condition. Apparently no previous case of this type has been reported, although several authors have noted neurofibromas of the vagus nerves associated with cutaneous neurofibromatosis. Gerbode and Margulies have recently reported a case of this latter type and reviewed the literature on this subject.

This present case of multiple bilateral neurofibromas confined to the vagus nerves presented certain questions as to the optimum surgical management at the time of thoracotomy because of the presence of large but apparently benign neurofibromas proximal to the origin of both recurrent laryngeal nerves. In addition, postoperatively this patient has afforded a unique opportunity for observation and study of the physiologic effects upon the heart and other organs of bilateral high cervicothoracic vagectomy in man.

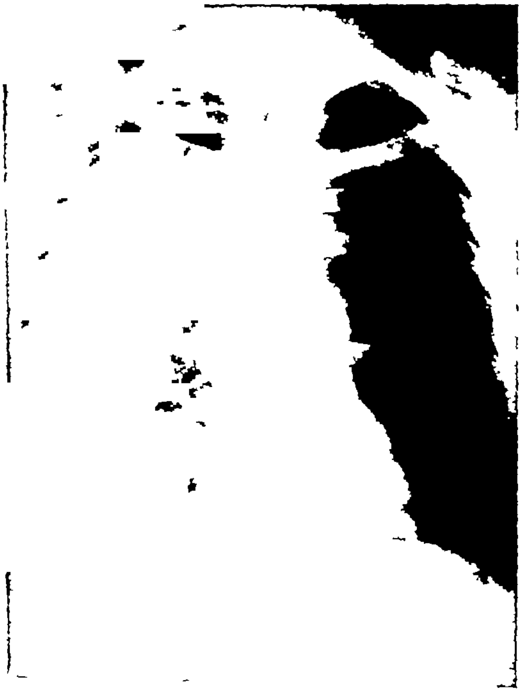

Fig 1—Preoperative chest roentgenogram showing bilateral nodular soft tissue densities projecting laterally from the mediastinum at the level of the aortic arch.

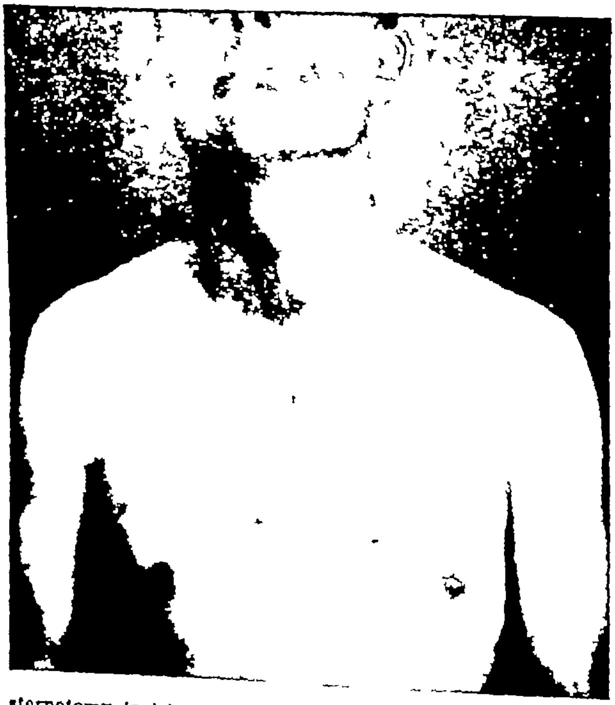

Fig 2—Median sternotomy incision with bilateral extensions into the third intercostal space (six weeks postoperatively)

On Jan. 29, 1953, the patient was taken to the operating room, and under Pentothal curare nitrous oxide anesthesia, with the patient in the supine position, the chest was opened by a midline sternotomy incision, which was extended bilaterally into the right and left third intercostal spaces. Later in the operation, the incision was extended into the neck in the midline to the level of the hyoid bone (Fig. 2).

The superior mediastinum was then explored. On the left side, a multilobed string of tumor masses was noted to cross anterior to the arch of the aorta. Exploration revealed that the course of these masses was consistent with that of the left vagus nerve. Superiorly, the upper extent of these tumor masses was at the level of the carotid bifurcation. Above that level, the short remaining trunk of the left vagus nerve appeared normal. Inferiorly, the lowermost mass lay behind the pulmonary hilus below the origin of the left recurrent laryngeal nerve. This segment of tumor masses, about 16 cm. in length, was completely removed without difficulty. Exploration of the right side of the mediastinum revealed that the right vagus nerve was afflicted in a similar manner. The lowest mass on this side was the size and shape of a hen's egg, and lay behind the superior vena cava just as it entered the right atrium. Superiorly, this mass terminated in normal appearing vagus trunk at the level of the right subclavian artery, a few millimeters below the origin of the right recurrent laryngeal nerve (Fig. 3). Just above this short segment of grossly normal vagus trunk and proximal to the origin of the right recurrent nerve, however, another tumor mass involving the cervical vagus trunk was evident. The lower tumor was removed by amputating the vagus trunk superiorly 1 or 2 mm. below the origin of the right recurrent nerve and inferiorly just below the tumor mass. By so preserving the right recurrent laryngeal nerve, it was necessary to leave one remaining neurofibroma undisturbed in the neck on this side.

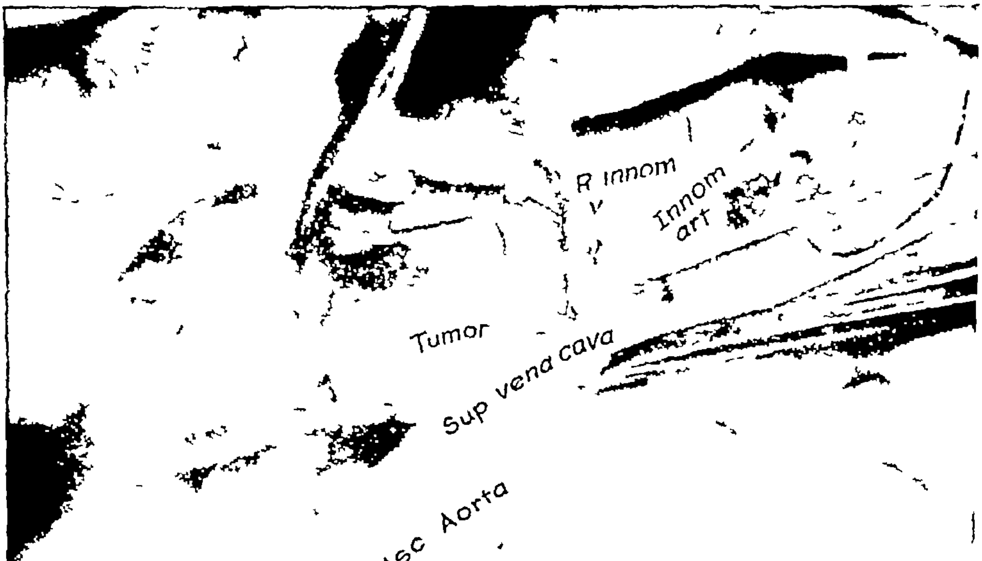

Fig. 3.—Appearance at operation of the neurofibroma of the right vagus nerve located behind the superior vena cava.

The patient tolerated the procedure well, except for an abrupt rise in pulse rate from a constant 80 to 110, and a drop in blood pressure from 160 to 140 at the time of severance of the second vagus trunk. After this, the blood pressure slowly rose to 150, the pulse rose to 120 and remained there for the remaining duration of the surgery The patient was laryngoscoped just before leaving the operating room, the left vocal cord was noted to be paralyzed, but the right cord moved normally

Gross examination of the surgical specimens indicated that the tumors varied from small nodules to egg sized masses (Fig 4) Between these tumor masses and below the lowest ones the vagus trunks appeared to be normal The attached portion of nerve trunk could be traced for some distance into the masses Gross pathologic examination of the removed tissue showed that the tumor of the left vagus nerve was 16 cm long, measured 2 5 cm in its greatest diameter was encapsulated and lobulated and was soft in consistency Microscopic examination disclosed a loose, fibrous structure with small spindle shaped cells scattered through a reticular and edematous stroma A thin, fibrous capsule was present The tumor of the right vagus nerve was 6 cm long and the mass had a similar gross and microscopic appearance to that on the left The pathologic diagnosis was neurofibromas with no evidence of malignancy

Fig 4—Intrathoracic neurofibromas of the right and left vagus nerves removed at surgery The egg sized mass lying behind the superior vena cava is shown above Below may be seen the complete string of neurofibromas involving the left vagus trunk from the level of the carotid bifurcation to the pulmonary hilus

While the patient was in the recovery room it was noted that his cough reflex was not present therefore the endotracheal tube was allowed to remain in place during that night and was not removed until the following morning This unusual tolerance to the endotracheal tube was further evidence of a diminished cough reflex, because at that time the patient was fully awake and had no difficulty in voluntarily coughing About one and one half days later it became apparent that a tracheotomy would be of value to aid tracheobronchial aspiration of secretions which tended to accumulate because of the poor cough reflex Thus tracheotomy was carried out on Feb 1 1953 By February 7 it was possible to plug the tracheotomy tube and the following day it was removed The remainder of the hospital stay was uneventful although the pulse rate remained consistently elevated until the time of discharge from the hospital on the thirteenth postoperative day

The pulse rate of 120 has continued virtually unchanged from the time of its abrupt rise at the severance of the second vagus trunk through the surgery during convalescence, and until the time of the patient's most recent visit to the outpatient department twelve months later Hoarseness which was marked while the patient was in the hospital was found to be considerably improved upon the last visit Epigastric fullness and 'belching' which were present for two or three months after surgery, have now disappeared, but a moderate diarrhea (four to six stools each day) still continues one year postoperatively. He is now able to work a full day on the farm, but states that he avoids "heavy" work. Although his neck appears to have some fullness to gross inspection, the tumor mass in association with the cervical trunk of the right vagus nerve is still not palpable one year after surgery. (The fact that there is no palpable enlargement in the right cervical region is probably because of the soft consistency of the tumor mass and its position deep to the sternocleidomastoid muscle.)

DISCUSSION

Nearly all neurogenic tumors of the mediastinum arise from the paravertebral sympathetic nerve trunks and the intercostal nerves, therefore, they are usually found in the posterior mediastinum. In unusual cases, such as in the patient herein reported, they may arise from other nerves and thus may be encountered elsewhere in the mediastinum.

It is of interest in this patient that preoperatively, at a case presentation seminar, an experienced consultant in chest diseases questioned the need for thoracotomy in this patient because the roentgenographic appearance and the location of the masses were considered pathognomonic of lymphoblastoma. It has been our opinion, however, that the relative safety that attends thoracic surgical procedures has outmoded, in most instances, the use of the therapeutic test dose of radiation that was suggested by this consultant as a means of diagnosis. Further, thoracotomy not only permits an accurate diagnosis in such cases but prevents the occurrence of tissue changes secondary to increasing compression of adjacent organs that may make subsequent surgical removal of even benign lesions more difficult or even impossible. Likewise, in certain benign tumors it is possible that removal will forestall later death caused by malignant transformation.

When it became apparent, at the operating table, that the vagus nerves were involved bilaterally with neurofibromatoma from the level of the carotid bifurcation in the neck to below the origin of the recurrent nerves distally, the decision was made to remove the tumors completely on the left side (where the cervical masses were larger than on the right side) thus sacrificing the left recurrent laryngeal nerve, and to remove all the tumor in the right mediastinum (where the masses were larger than on the left side) up to the origin of the right recurrent nerve. This necessitated leaving at least one tumor mass in the right side of the neck, the lower pole of which was located at the level of the right subclavian artery. Several considerations entered into this decision. To remove completely all of the tumors would have necessitated bilateral sacrifice of the recurrent laryngeal nerves, which is incapacitating. Several consequences make bilateral loss of the recurrent laryngeal nerves a far more crippling procedure than unilateral removal. First, there is loss of speech; second, physical activity is severely curtailed due to inability to increase ventilatory volume because of obstruction to air flow by the paralyzed cords; and finally, there is the obnoxious "crowing snore" which is regularly present during sleep. Other considerations were that the tumors were probably benign and that one recurrent nerve could be spared, and yet all the intrathoracic tumors could be removed leaving only the one neurofibroma remaining in the neck where it could be followed by palpation and attended to surgically with relative ease if the need should arise later

PHYSIOLOGIC CONSIDERATIONS

It is likely that a fairly complete interruption of the parasympathetic innervation to the heart and lungs (as well as to the abdominal viscera) was achieved in this patient therefore, it seemed pertinent to assess some of the effects of this procedure in this patient

Bilateral section of the vagus nerves in the neck is said to be uniformly fatal in laboratory animals because of its effect on the cardiorespiratory organs[2] Markowitz[3] stated however that in the dog if the right vagus nerve is sectioned below the origin of the recurrent laryngeal nerve, the left vagus nerve may be sectioned in the neck without fatal outcome The present case confirms in man this latter observation

The difficulty that our patient had with retained secretions (requiring tracheotomy) however suggests that the protective reflexes of the respiratory tract are seriously, but probably temporarily impaired by vagectomy at this level There are several possible explanations for these observations Action of the cilia is said to be independent of nervous control but the efficiency of ciliary action is dependent in a large part on the character of the mucous secretions of the respiratory epithelium It is quite possible that the secretions are adversely influenced by vagotomy as also may be bronchial peristalsis[4, 6] It is also likely that paralysis of one recurrent laryngeal nerve, with the associated vocal cord paralysis seriously interferes with the efficiency of the cough reflex because of the virtual impossibility of maintaining a closed glottis against which to expire forcibly and then suddenly open, as occurs normally in the act of coughing The observation by Kuntz[7] that the cough reflex may be elicited by stimulation of the vagus fibers distributed to any part of the respiratory tree and the experiments of Cromer and associates[8] wherein it was noted that bilateral section of the vagus nerves markedly reduced the cough reflex which was manifested following the insufflation of ammonia vapor into the trachea of experimental animals emphasize additional reasons for this patient's diminished cough reflex

In view of the extent of the vagus resection and the known vagus pathways to the heart it is likely that the heart was virtually completely deprived of its parasympathetic innervation while its sympathetic innervation remained intact The persistently fast pulse rate still present one year after surgery, and a failure of atropine (1/100 grain) to increase this rate add further support to this conclusion Moreover it is a finding of particular interest that in this patient with extensive cervicothoracic vagectomy both the systolic and diastolic blood pressures have remained for twelve months now persistently elevated by about 20 mm Hg above their preoperative levels

Because of the unusual opportunity offered by this case for study of the effect of vagectomy upon cardiac function Dr Fraser and Dr Chapman[*] have studied this patient's cardiac rate blood pressure and cardiac output in response to exercise four months after surgery The results of these observations are reported in detail elsewhere,[10] but in summary several interesting observations were made, as follows in the resting state the patient had a persistently high pulse rate (120/min), this rate increased in response to exercise The magnitude of this increase in pulse rate, however, was distinctly less than normal On the other hand, the responses to exercise of the cardiac output blood pressure, and circulation time were all within previously observed normal limits for the work load used

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These observations add further evidence that man has nonvagal mechanisms for increasing cardiac rate and cardiac output in response to exercise The fact that the magnitude of the increase of the cardiac output in response to graded exercise was normal in this patient, whereas the pulse rate increase was less than normal, indicates that readjustment was brought about in part by an increased stroke volume These studies also complement those of Smithwick and associates,[11] who found that sympathetic denervation of the heart in man uniformly resulted in a slowing of the heart rate and a reduction of the pulse rate increase in response to exercise

SUMMARY

A case of bilateral cervicothoracic neurofibromas of the vagus nerves without cutaneous neurofibromatosis or evidence of neurofibromas elsewhere in a 40-year old man is presented The surgery performed in removing these tumors involved an extensive cervicothoracic vagectomy, intentionally sacrificing the left recurrent laryngeal nerve but preserving this nerve on the right side

Postoperatively, some physiologic observations have been made upon the effects in this patient of cervicothoracic vagectomy upon cardiorespiratory function These alterations in function consisted of a diminished cough reflex persistently elevated pulse rate and blood pressure, a normal cardiac output with a normal response to exercise, but a diminished pulse rate response to exercise, and a lack of any detectable response of this elevated resting pulse rate to a therapeutic dose of atropine Some of the physiologic implications of these observations are briefly discussed

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A METHOD FOR MEASURING TIDAL AND MINUTE VOLUMES IN PATIENTS UNDER REGIONAL AND GENERAL ANESTHESIA

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THE determination of tidal and minute volumes in the anesthetized patient requires the introduction of the measuring meter between the circle-flow system of the gas anesthetic machine and the breathing mask or intratracheal tube. This is necessary because the volume of gas flowing in the afferent and efferent limbs of the circle system of the anesthetic machine bears no fixed relation to the volume moved in respiration of the patient. This same situation pertains in "to and fro" systems to a somewhat less degree but still of sufficient magnitude to require special arrangement of the metering.

The major reason for this is that the concentrations of the various gases, such as N_2O, and O_2 in the anesthetic mixture, are maintained by allowing wide margins of excess flow of these gases to enter the system at constant rates with the excess escaping at the machine end of the exhalation side of the anesthetic tubing. Other spill over methods are also used but all allow the flow of sizable quantities of gases which have no participation in the respiration of the patient through the anesthetic machine.

The second requirement for simple direct metering is the division of the airway into inspiratory and expiratory channels without the interposition of any dead air space or resistance to flow. This allows metering to be accomplished by the measurement of a unidirectional gas flow.

The introduction of a properly valved circle system between the orifice of the gas machine tubing and the patient's mask or intratracheal tube will accomplish the division of the flow into inspiratory and expiratory channels. These channels are unaffected by the flow or pressures occurring in the anesthetic machine or its tubing. The flow in this system will be entirely dependent upon the volume of gas entering and leaving the patient's airway. (See Fig. 1.)

This schematic diagram has purposely simplified the gas machine omitting its valving, soda lime, bag, inflow channels and variable pressure escape port. The two channels interposed between the gas machine and the intratracheal tube are valved so that as the pressure on the gas machine side rises above the intratracheal pressure the valve on the inspiratory limb opens whereas the valve on the expiratory limb closes allowing gas to flow from the machine through the inspiratory side into the lungs. A reversal in pressure relations closes the inspiratory valve and opens the expiratory valve to allow gas flow

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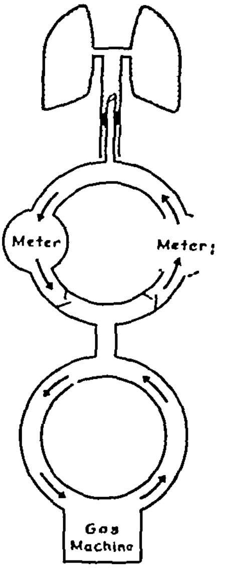

Fig 1 —A simplified schematic drawing of a closed anesthesia circuit with the gas meter in either the inspiratory or expiratory arm The meter records only the actual volume of gas that the patient inspires or expires regardless of any leak in the gas machine

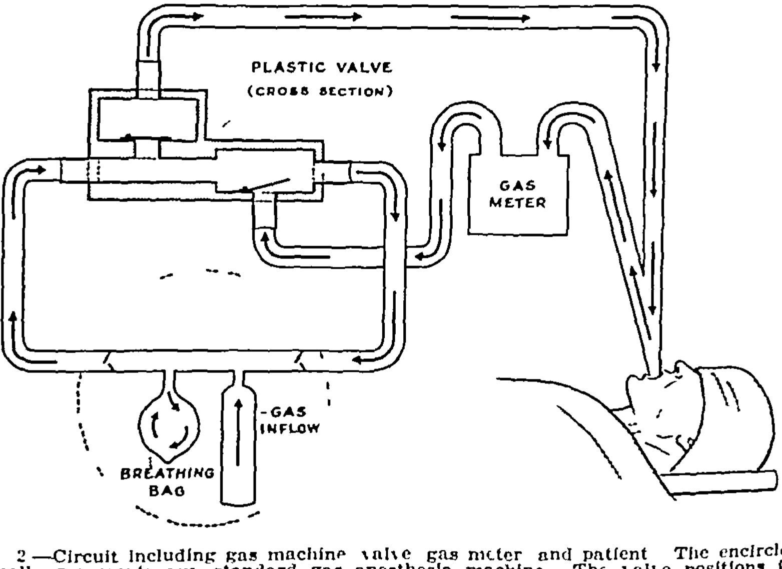

Fig 2 —Circuit including gas machine valve gas meter and patient The encircled area schematically represents any standard gas anesthesia machine. The valve positions indicate the expiratory phase of respiration

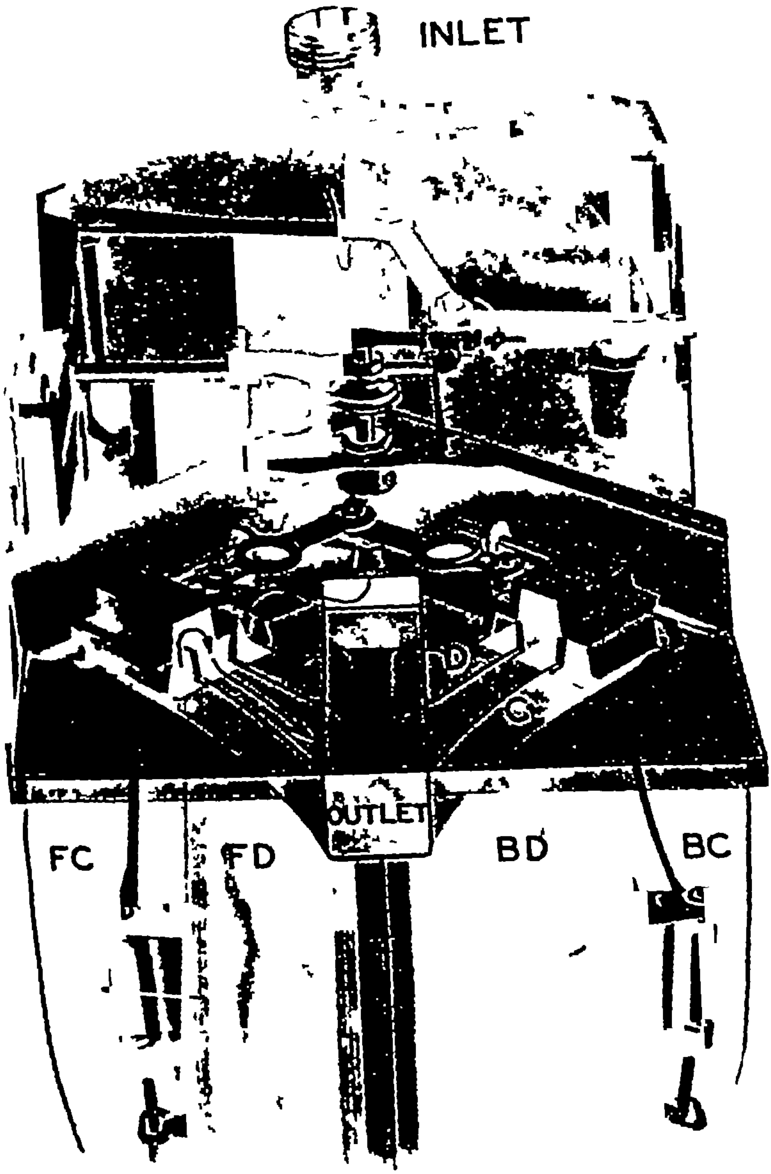

Fig. [illegible].—A section of the volume displacement meter.[1]

FC—front case compartment
FD—front diaphragm compartment
BD—back diaphragm compartment
BC—back case compartment
D—port to diaphragm compartment
C—port to case compartment

When the valves are in this position *FD* is filled and *FC* is emptied. Gas entering through the inlet pipe [illegible] through the port of the front diaphragm compartment, filling it. At the same time *FC* is being emptied, gas leaving through the port of the front case compartment and meter outlet. The front disk is moving away from the center partition moving the front flag arm toward the center of the meter, rotating the tangent arm and crank in a clockwise direction and moving the back valve in the direction of the arrow, thus opening the back ports so that gas can enter *BC* and leave *BD*.

through the expiratory limb. Because there is always a slight pressure gradient in one direction or the other across this system, one of the valves is always closed, and circling is avoided.

Fig. 2 is a schematic drawing designed to show the valving. It again greatly simplifies the gas machine and is inaccurate in depicting the intratracheal tube connection. The channels leading into and out of the broken line circle represent the gas machine tubing. Note that they communicate through the valve block without any valving. The valves are arranged to allow flow out of one tube to the patient when the pressure in the trachea is less than in the machine. The flow is through another tube when the intratracheal pressure is higher than in the machine system. The diagram depicts the inflow and outflow tube joining before meeting the intratracheal tube. This is in error, as it would materially increase dead space. In actual application, these tubes are standard anesthetic tubing or one-inch flexible but rigid smooth-bore plastic tubes attached to a standard intratracheal fitting or mask fitting. The meter is shown here in the expiratory side which is preferable. The valve block is of clear plastic, allowing visualization of valve action at all times.* The valves are rubber-faced gravity type made of brass disks hinged at one point. The block should be made so that it can be disassembled for servicing and cleaning but it must be airtight.

METERING

We have found that the ordinary volume displacement meter (manufactured by the American Meter Company) of the type used by most commercial gas companies for dwelling installation is very satisfactory. The American Meter Company rates these meters as being accurate within 0.25 per cent and offering resistance of 0.25 cm. H_2O at 9.44 liters per minute. Our measurements show them to be accurate within 1 per cent and to offer less than 1 cm. H_2O resistance at flows less than 60 liters per minute. These meters are encased in opaque metal boxes, and a description of the structure of such a meter may be found in the literature.[1]

These meters record in cubic feet. For convenience a long hand was substituted for the conventional index on the one half cubic foot scale, and a large dial calibrated in liters was placed behind this hand. For minute volume studies a stop watch must be used with the meter for timing. Tidal volumes may be read directly from the liter scale.

The meter may be placed in either the inspiratory limb of the circuit or the expiratory side. The latter is preferable if positive pressure assisted or controlled respiration is carried out, as any leakage of the mask or about the intratracheal cuff will occur during the positive pressure inspiratory phase. Stead and associates[2] subsequently adopted this system of divided airway and metering in studies on patients undergoing thoracic surgery. They found no appreciable difference in minute volume readings from placing the meter in either the inspiratory or expiratory arm of the circuit with a tight fitting intratracheal tube.

For evaluation of this system and as a base line for further studies, normal subjects under local or spinal anesthesia were studied. These patients were all fully conscious, had no airway difficulties, and experienced no sense of dyspnea or showed any increase in respiratory rate or effort while breathing through the equipment by means of a tightly fitting face mask.

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*A sticking valve allows to and fro motion, producing a large dead space of real hazard to the patient.

A gas machine was not used in these subjects, but rather the ports on the valve block where the gas machine tubing attaches were left open to exchange room air. Minute volume in these subjects ranged between 5.02 liters per minute to 8.22 liters per minute varying with the size of the subject, his pain, and anxiety.

A study of normal subjects under general anesthesia having abdominal or extremity surgery using either a tightly fitting face mask or a cuffed intratracheal tube showed minute volumes ranging from 8.22 liters per minute to the woefully inadequate figure of 0.85 liters per minute depending upon the depth of anesthesia and efficiency of respiratory assistance provided by the anesthetist.

CONCLUSIONS

1. Accurate tidal and minute volumes may be determined by providing a double-channel airway properly valved to avoid to-and-fro dead space and by separating the flow into an inspiratory channel and an expiratory channel. The respiratory airway may be divided into inspiratory and expiratory channels by proper valving of a double-channel airway without increasing to-and-fro dead space.

2. This system may be attached to a tightly fitting face mask or cuffed intratracheal tube and the flow measured in either channel by an accurate low impedance meter for the determination of tidal and minute volumes in conscious or unconscious subjects.

3. This system may be interposed between the outlet of the usual gas machine tubing of either circle or to-and-fro systems without disturbing the gas flows occurring in the gas machine or its tubing, without interfering in any way with the anesthetist's management of respiration and without recording any volumes except those actually exchanged by the patient.

4. An ordinary volume displacement meter of the type usually used by commercial public service gas companies for dwelling installations manufactured by the American Meter Company is admirably suited for measurements of this nature, being sufficiently accurate and having very low flow resistance.

5. Minute volumes under low spinal anesthesia and regional anesthesia are well maintained in the normal physiologic range, whereas with general anesthesia they frequently fall to dangerously low levels.

6. Continuous measurement of minute volumes is essential for the interpretation of data relating to the oxygenation and carbon dioxide elimination of subjects under general anesthesia.

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STAGED AND SIMULTANEOUS BILATERAL PULMONARY RESECTION FOR TUBERCULOSIS

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THE frequency of bilateral pulmonary tuberculosis and the development of pulmonary resection as a form of surgical treatment provoke consideration of bilateral resection. The bilateral approach can be carried out either in stages or simultaneously. The experience to be reviewed in this report is comprised of twelve staged and three simultaneous procedures. Fifteen patients underwent a total of twenty-seven operations without any deaths.

Pulmonary resection for tuberculosis since the first successful planned lobectomy in 1934 has enjoyed an increasing and deserved popularity.[1,2] Reports since the advent of antimicrobial preparation have been encouraging.[3,4] The incidence of bilateral surgery is not as high as one might expect. Chamberlain reported a series of 300 segmental resections with ten bilateral cases.[5] Kelley listed nine bilateral resections in 104 cases.[6] A possible explanation is that the contralateral lesion may regress in the interim between the initial and second operations. This has been our experience in a number of instances where prior to the first operation the period of repetitive x-ray observation has been relatively brief. Staged bilateral resection, nevertheless, has a definite place in the surgical treatment of pulmonary tuberculosis. The idea of simultaneous bilateral resection is attractive because it offers a single operation rather than two with a substantial time interval. Another point in favor of the simultaneous program is the obligatory participation of all residual segments in the respiratory effort. This may provide a more efficient respiratory apparatus than is available to the staged patient whose first side doubtless carries the major share of respiratory function. Where pulmonary capacity has been reduced by initial surgery, respiratory function may be critical. Cyanosis has been noted following completion of the staged procedures. One patient (Patient 9 of the staged group) required tracheotomy to decrease the dead space and to insure lung capacity against atelectasis. There was no cyanosis in any of the simultaneous bilateral segmental resections.

Possibly the first simultaneous bilateral thoracotomy was performed by Bloch of Danzig in 1882.[7] The patient was a young woman who requested the operation for her suspected tuberculosis. Normal lung was found at operation, which may have persuaded Bloch to open the contralateral chest. It is not clear whether any resection was performed; however, no disease was found

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The patient expired either on the operating table or very early in the postoperative period. Legal proceedings were instituted, and Block took his own life.[8] The actual circumstances surrounding this clinical misadventure are somewhat equivocal. Block as well as Theodor Gluck of Berlin published experimental pulmonary resections on a variety of animals including dogs, pigs, rabbits, horses, and even cows.[9-11] No simultaneous bilateral resections were performed experimentally. The technique consisted of exteriorizing a pulmonary lobe through a small intercostal incision, applying a tourniquet-ligature about the secondary hilus and excising the lobe. A clinical case had been similarly treated by Kirchhoft in 1876.[12]

Much has been said concerning bilateral resections for bronchiectasis.[13-16] Overholt in 1952 reported the first simultaneous bilateral pulmonary segmental resection for bronchiectasis.[17] An inspissated tuberculous cavity was removed by wedge excision from the posterior segment of the left upper lobe in one patient; otherwise the three cases described were unrelated to pulmonary tuberculosis.

SELECTION OF PATIENTS

Our experience corroborates the proposition that tuberculosis usually inhabits the apicoposterior segment of the left upper lobe, the apical and posterior segments of the right upper lobe, and the superior segments of either lower lobe. This does not mean that segmental boundaries are respected by the tuberculous process, but in general, the site is predictable from x-ray films. Here and there an adjacent subsegment must be sacrificed to excise the principal disease. This is readily done when indicated. In spite of this remarkable constancy of position, one must adapt himself to the disease encountered and not perform a segmental resection for tuberculosis which is of lobar or greater dimension. Planigrams in particular are helpful in avoiding this pitfall. Bronchoscopy also is valuable since the patient with endobronchial disease must have either a longer period of chemotherapy or a more extensive operation.

All cases in either group are of patients at the Anoka State Mental Hospital and therefore carry the additional problem of severe mental illness. Bed rest is an impossible discipline, and incidentally, the consequences of its absence have not been striking. A patient is chosen for bilateral resection who over a period of time usually one or two years has been unable to secure x-ray clearance for return to the general population of mental patients. Medical treatment has been unable to eradicate the disease which is well localized to the upper lung fields in most cases. There must be direct bacteriologic evidence of tuberculosis in the form of culture or guinea pig inoculation. Antimicrobial drugs are now given for at least three months prior to surgery.

If clinical findings, x-ray investigation and bacteriologic history indicate that a patient is definitely a candidate for bilateral surgery, the next question is whether the plan should be staged or simultaneous. Here physical condition becomes the supreme consideration. One cannot expect a robust subject when he is dealing with a patient who requires bilateral operations, but only the best risk group should be relegated to the simultaneous plan. Our simultaneous bilateral experience at this time has been at the segmental level; nevertheless it is conceivable that lobectomy either paired or in combination with segmental resection could be carried out if clinical conditions warranted. Seldom, if ever, should the surgeon reach a situation where the resection on one side has become so formidable that the second side must be abandoned. Careful roentgenographic work-up should prevent this occurrence. Simultaneous bilateral resection is feasible in that patient who requires bilateral surgery and whose general condition is reasonably good.

TECHNICAL CONSIDERATIONS IN SIMULTANEOUS BILATERAL RESECTIONS

The supine position is used with a sandbag along the dorsal vertebral column to elevate the mediastinum. A transverse incision is made in the third anterior intercostal space cutting across the sternum. This provides excellent exposure of either hilus and permits the use of two operating teams at least until both lungs are freed of adhesions and hilar dissection begun. At this point the operating table is rotated for better access to the hilus under consideration. The indicated procedure is carried out on the more involved side first with the contralateral resection to follow. Total operating time is little more than for the customary unilateral segmental resection. No real problem is occasioned by the bilateral pleural opening. Experiences with other forms of chest surgery have demonstrated the relative ease with which this situation is tolerated.[18] Postoperatively it is advisable to attach the chest catheters on either side to separate suction systems. Adapters and Y tubes connecting the chest catheters to suction should be made of unbreakable material. There probably ceases to be a communication between the two chest cavities after twenty-four hours.

A Pentothal-curare mixture is employed for induction and endotracheal intubation with subsequent addition of nitrous oxide and oxygen in a 1:1 ratio. This permits use of the electrocautery unit in the early stages of the procedure. Since cyclopropane interferes little with circulatory homeostasis and allows delivery of a 90 per cent oxygen content in the gas mixture, this agent is used for maintenance as soon as the cautery is dispensable. The lungs are inflated to the extent that there is no encroachment upon the surgical field. Respirations are either assisted or controlled thoughout. Slight Trendelenburg position is helpful in neutralizing the loss of negative intrapleural pressure and aids venous return to the right heart. This position also facilitates the removal of secretions by the endotracheal suction catheter.

DISCUSSION OF EARLY RESULTS

Since the first of the staged procedures was completed little more than one year ago it is much too early to speak in terms of end results. The total experience is summarized in Tables I and II. Criteria for discharge from the tuberculosis section must be rigid because of the congested living area to which mental patients are necessarily returned. Clinical and x-ray clearance plus

TABLE I GROUP I, STAGED BILATERAL RESECTIONS

PATIENT	AGE SEX	DATE 1ST OP	1ST OP	DATE 2ND OP	2ND OP	REMARKS
1	28 F	1-16-52	Ap and p segs RUL	1-19-53	Ap p and ant segs LUL sup seg LLL, 3 rib thoracoplasty	No complications, x ray, clinical and gastric clearance
2	49 M	2-6-52	Ap p seg LUL, 4 rib thoracoplasty	6-22-53	Ap and p segs RUL, wedge sup seg RLL	Wound dehiscence after 2nd operation
3	40 M	6-18-52	Ap p seg LUL wedge sup seg LLL	12-3-52	Ap and p segs RUL wedge sup seg RLL	Gastric relapse
4	50 M	6-25-52	Ap p seg LUL	1-5-53	Wedge ap seg RUL	No complications x ray, clinical, and gastric clearance
5	54 M	7-7-52	RL Lobectomy, 4 rib thoracoplasty	11-17-52	Ap p seg LUL	No complications x ray clinical and gastric clearance
6	50 M	7-16-52	Ap and p segs RUL	11-2-53	Ap p seg LUL	Post 2nd op air leak eventually resorbed
7	57 F	8-4-52	RL Lobectomy	1-26-53	Ap p seg LUL	No complications x ray, clinical and gastric clearance
8	55 F	1-14-53	Ap and p segs RUL wedge sup seg RLL	5-20-53	Ap p seg LUL	No complications x ray clinical and gastric clearance
9	50 F	1-25-53	Ap p seg LUL	5-25-53	P seg RUL, wedge ant and ap segs RUL	Post 2nd op, cyanosis tracheotomy
10	45 M	2-11-53	Ap and p segs RUL	10-26-53	Ap p seg LUL	No complications
11	67 M	3-4-53	Ap and p segs RUL	12-23-53	Ap p seg LUL	No complications
12	62 M	3-11-53	Ap p seg LUL	12-7-53	Ap and p segs RUL	No complications

TABLE II GROUP II SIMULTANEOUS BILATERAL SEGMENTAL RESECTION

PATIENT	AGE SEX	DATE OF OP	MORE INVOLVED	CONTRALATERAL	REMARKS
1	23 M	1-6-54	Ap p seg LUL wedge lingula	Ap and p segs RUL	No complications
2	42 M	1-20-54	Ap and p segs RUL	Ap p seg LUL	Air leak on right responded to increased suction
3	35 M	2-2-54	Ap and p segs RUL	Ap p seg LUL	No complications

six negative gastric lavage cultures represents a reasonably strict program. Antimicrobial therapy is continued for six months into the postoperative convalescence. In the staged group drugs are given continuously between operations. One month is permitted to elapse after drugs before the gastric lavage series is initiated. Typical preoperation and postoperative chest films in both the staged and simultaneous groups are seen in Figs. 1 and 2. To this date one case has developed evidence of persistent disease (Patient 3 of the staged group). The postoperative work-up is complete on five other patients and fractional data are encouraging on the remainder. The simultaneous bilateral

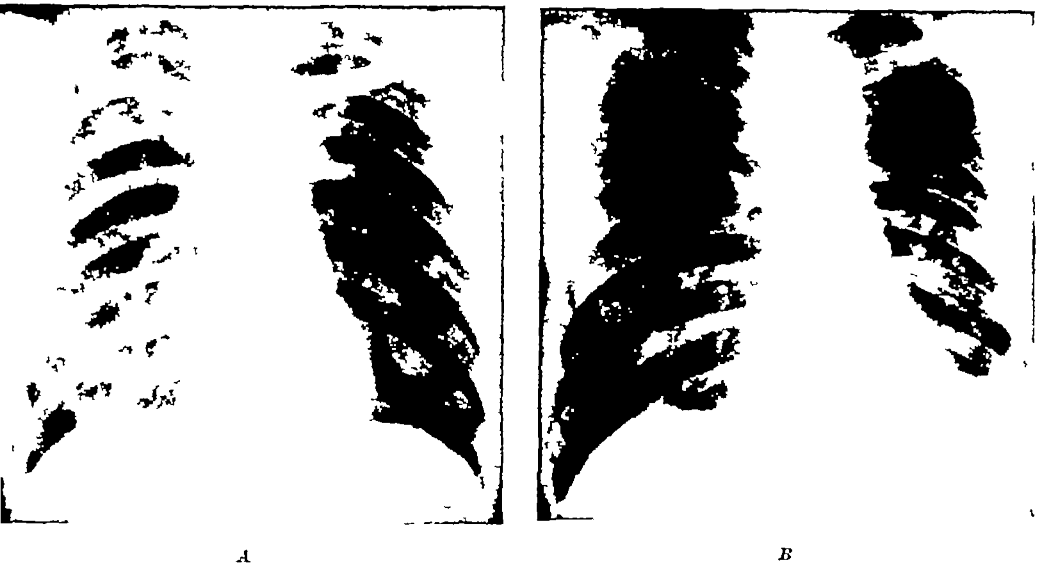

Fig. 1.—Patient 10 of the staged group. *A*, preoperative roentgenogram. *B*, two months following completion of bilateral resection.

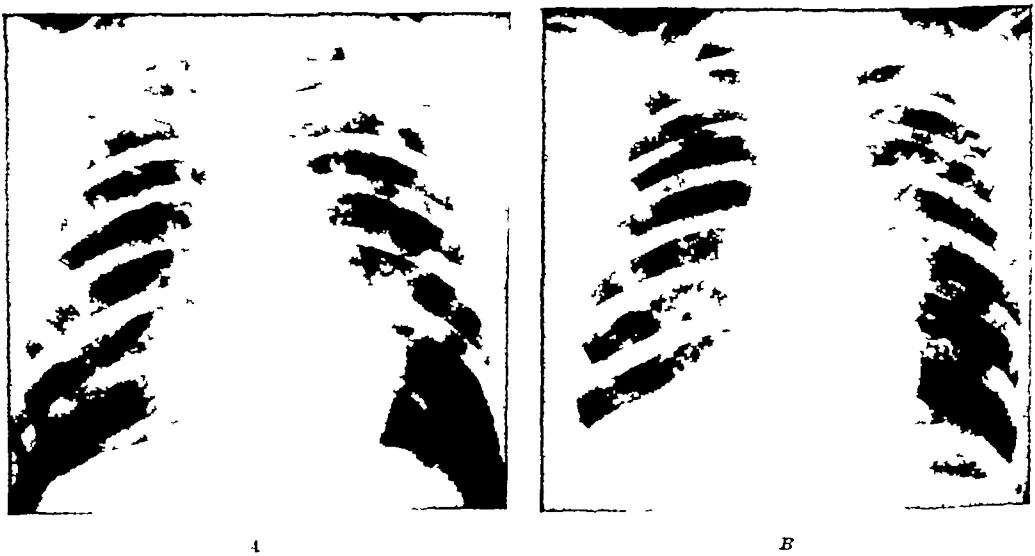

Fig. 2.—Patient 1 of the simultaneous group. *A*, preoperative roentgenogram. *B*, two months *following simultaneous bilateral segmental resection.*

resections are of course still receiving chemotherapy. The one positive gastric developed in the staged series where only two weeks of streptomycin and isoniacotinic acid hydrazide had constituted the preoperative preparation. It now appears that the persistent disease in this patient is from an area corresponding to the superior segment of the left lower lobe where a wedge resection was performed. Incomplete resection could well play a part in the gastric relapse.

COMMENT

The introduction of simultaneous bilateral segmental resection for pulmonary tuberculosis should prove of definite value in selected cases. With the anterior two team approach there are few technical hazards. One case manifested a severe air leak on the right immediately postoperatively (Patient 2 of the simultaneous group). By dividing the suction so that a pressure of 40 cm. of water was available to the right thoracic cavity while the left was maintained on 15 to 20 cm., the residual lung expanded to its full capacity. None of the three simultaneous cases developed any breathing difficulty. The union of the sternal joint must be firm to prevent excessive pain which could embarrass respiration as well as compromise the cough reflex. Bronchoscopy and planigrams in selecting simultaneous bilateral cases are very important. Finally, as in all excisional treatment for pulmonary tuberculosis the operation indicated by the disease must be performed. This requires careful preoperative evaluation. Wedge resections alone seldom constitute an adequate procedure. In such instances as these it is doubtful that the surgery was justified; if it was justified, spread or persistent disease is a real possibility.

SUMMARY AND CONCLUSIONS

1. Bilateral pulmonary resection for tuberculosis is a safe and practical procedure.

2. Twelve patients were subjected to staged bilateral resections without any deaths. One gastric relapse has occurred; otherwise, early results are favorable.

3. Simultaneous bilateral segmental resection is suggested for the relatively good risk patient who requires bilateral surgery. The advantages of the simultaneous approach are discussed.

4. Operations in three simultaneous bilateral cases have been performed without serious incident. An anterior transverse sternotomy incision is used with the two team operating system.

ADDENDUM

Since this paper was submitted for publication five additional simultaneous bilateral resections have been performed without mortality. In one case right upper lobectomy was combined with an apicoposterior segmental excision on the left to substantiate the contention that resection need not be limited to the segmental level.

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DICED CARTILAGE FOR CHEST WALL DEFECTS

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THE resection of two or more segments of ribs together with periosteum and intercostal muscles, deprives that portion of the thoracic wall of its normal stability and results in herniation of the lung and paradoxical motion during respiration. The severity of these effects depends on the size of the defect and the amount and thickness of the structures overlying it. Underneath the scapula or the trapezius and rhomboidei muscles, the effects are minimal, but when ribs are removed from the lateral chest wall, where there is the least amount of muscle tissue, paradoxical motion is most severe. For over sixty years various methods have been used to restore the stability and protection of the chest by securing a firm closure of chest wall defects. The introduction of the use of antibiotics and tantalum stimulated greater interest and additional attempts to solve this problem.

L. Mayer,[18] in 1941, reported the successful use of a free graft of fascia lata to close a large chest wall defect following the removal of a chondrosarcoma of a rib. Watson and James[21] reported similar success in 1947. Davis and associates[7] and Campbell,[6] in 1950, mobilized and transplanted the latissimus dorsi over a free fascia lata graft to give added support to close a large chest wall defect. Effler and Blades,[10] in 1946, and Beardsley,[2] in 1950, reported the unsuccessful use of rigid tantalum plates. The plates had to be removed because of persistent drainage and infection. Uniformly successful closures were obtained with the use of tantalum gauze by Beardsley and Cavanaugh,[3] Morrow,[16] and Ada and Hevenor.[1] Maier[13] mobilized and used the breast to protect anterior chest wall defects. Pickrell and associates[15] utilized skin and muscle pedicle flaps and Prioleau[19] used full-thickness skin flaps to cover the defects. Mauer and Blades[14] mobilized segments of adjoining periosteum and split segments of ribs to cover small and medium-sized defects. Kinsella and associates[12] divided a tibial graft into segments and Bisgard and associates[4] used mortised split rib grafts to overcome sternal defects following the resection of sternal tumors. Hardin and associates[11] reported the successful use of preformed Lucite plates to cover large chest wall defects. Blades and Paul,[5] however, reached the conclusion "The use of tantalum plates and other foreign bodies is unnecessary and unsatisfactory" and transplants of fascia lata "are rarely necessary."

The method described by Mauer and Blades[14] appears to be the best for the small chest wall defects because autogenous adjoining tissue is utilized to form a bony support. The only disadvantage of fascia lata or tibial grafts is that an additional operative procedure is necessary. Thus far it appears that

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Received for publication April [illegible] 1951 the most popular method for the closure of large chest wall defects is by the use of tantalum gauze. The desire to obtain a strong rigid cover over an exposed heart and the curved anterolateral portion of the chest wall provoked the idea in the authors to use diced cartilage between two layers of tantalum gauze.

Peer[17] was the first to utilize diced cartilage to cover skull defects in 1943. Subsequently, its use has been extended to restore shape in bony deficiencies of the face, for construction of ears, to form an articular surface of cartilage in ankylosed hips, to reinforce fascia in the repair of hernias, and to cover bony defects in spina bifida.

Diced cartilage grafts, as the name suggests, consist of numerous small segments of cartilage which can be packed or molded into any desired contour, like wet grains of sand. Diced cartilage can be quickly prepared by putting through an ordinary meat grinder pieces of cartilage preferably obtained from young subjects who have met death by accident. It may be stored indefinitely in a freezer "bank" until it is used. Microscopic examination of the diced cartilage grafts following transplantation at various intervals up to four years has been made. The sections demonstrated that the spaces between the small cartilage segments were occupied first by blood and later by ingrowing connective tissue accompanied by numerous small blood vessels. Each small cartilage graft rested against adjoining cartilage at some points with a thin layer of connective tissue between, thus preventing contracture of the cartilage mass. The collective bulk of the diced cartilage grafts was increased by the addition of the numerous small spaces between the pieces of cartilage, and for this reason, the diced cartilage grafts actually filled a larger space than the solid rib cartilage from which they were cut. Autogenous diced cartilage grafts had living chondrocytes, normal appearing matrix, with occasional bone formation in or outside the grafts and a general absence of invasion and absorption. Preserved diced cartilage grafts showed definite invasion and absorption in some grafts, whereas in others the matrix, with dead cells, appeared to resist invasion quite well. The tendency to bone formation was more pronounced in the preserved cartilage than in the autogenous cartilage. Connective tissue and blood vessels grow through the openings of the mesh and join the diced cartilage grafts into a solid structure. The ingrowing host of fibroblasts, together with collagenous fibers and cement substance provides a strong binding wall, in which the individual cartilage segments are firmly held together to protect the vital structures beneath.

CASE REPORT

B. McG., a white boy aged 15, on Aug. 1, 1942, was struck by an ice truck and sustained a crushing injury to his anterior chest wall with multiple rib fractures. He was treated conservatively and discharged from the hospital with a marked anterior chest wall deformity which consisted mainly of a depression involving the left fifth, sixth, seventh, and eighth costal cartilages and elevation and angulation of the right fourth, fifth, and sixth costal cartilages. In 1948, a plastic operation was performed at Mt. Sinai Hospital in New York to correct the deformity by resecting the deformed cartilages. As a result of an infection, a draining sinus persisted until October, 1950, when he was admitted to the New York Hospital. The draining sinus was excised, and a chronic empyema cavity was drained and a thoracoplasty performed Several operations were necessary to clear up the infection before healing took place in July 1951 At this time he had a right parasternal defect which involved the loss of about 4 cm. of the right fourth, fifth and sixth costal cartilages and a very large defect which involved the loss of the anterior fifth sixth, seventh and eighth ribs and cartilages The heart was covered only by the pericardium and a wide paper thin scar The scar extended horizontally from the sternum, where it was widest measured 8 cm., gradually tapered down to a linear scar in the left axilla and continued around the angle of the scapula. The entire anterior surface of the heart was covered by this thin scar so that the heart could be grasped with the fingers (Fig 1) Paradoxical motion was marked over the defects and the heart action was very apparent

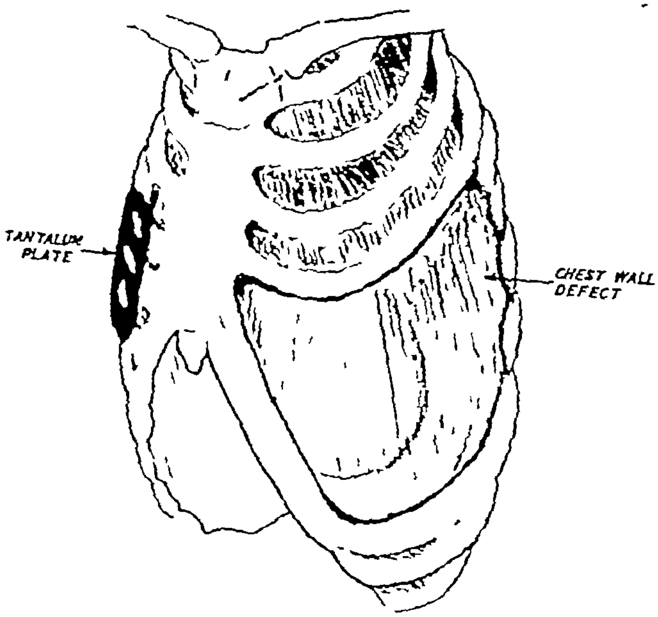

FIG 1—Thoracic cage showing the tantalum plate covering the bony defect on the right anterior chest wall following the first operation and the large chest wall defect on the left, through which the heart could be easily felt

He was repeatedly refused employment because of the large chest wall defect and exposure of his heart He became a client of the New Jersey Rehabilitation Commission because of his employment handicap He was admitted to the St Barnabas Hospital in Newark for plastic closure of the chest wall defects It was decided first to repair the right side by means of a tantalum plate fashioned to an oval shape to barely overlap the edges of the defect Three horizontal segments of the plate were cut out to correspond to the remaining intercostal spaces Small drill holes were made along the edge of the plate for steel sutures On June 20 1952 the scar was excised down to the pleura. The pectoralis muscle and fascia were mobilized and the ends of the ribs and edge of the sternum were exposed Suture holes were made in the ends of the ribs and sternum with a towel clamp The tantalum plate was firmly anchored with steel sutures over the defect (Fig 1) The pectoralis muscle and fascia were sutured over the plate with interrupted chromic catgut sutures and the skin was closed with silk. The wound was not drained, but it was necessary on two occasions to aspirate a small amount of accumulated bloody fluid The wound healed cleanly

The patient was readmitted to the hospital on Nov 12 1952 The tantalum plate on the right side had proved very satisfactory but this method was not considered for the left side because of the extent of the defect and mobility of this part of the chest The maximum protection and a certain degree of flexibility were desired and it was felt that a combination of diced cartilage and tantalum gauze would provide these advantages On November 17, the entire horizontal scar on the left chest, including the wide paper thin scar which was attached to the anterior pericardium overlying the major portion of the cardiac area was excised The scar was dissected off the anterior pericardium and the lingular portion of the upper lobe of the left lung The overlying thickened pleura was decorticated and the atelectatic lingula freed and re-expanded The incision was developed by reflecting the skin subcutaneous tissue and muscles off the fourth and ninth cartilages and ribs The fifth sixth, seventh, and eighth cartilages and anterior ribs were missing from the sternum to the left axilla as a result of the previous operations (Fig 1) The fourth and

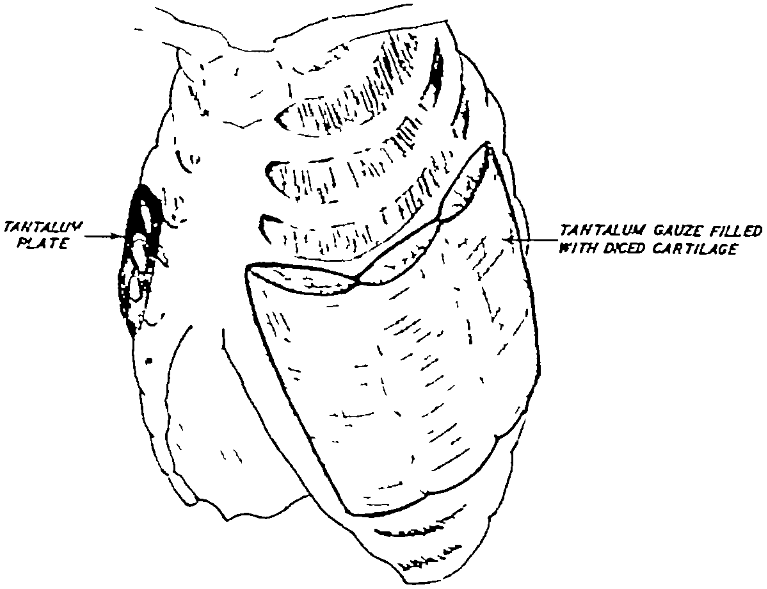

Fig 2—Shows the large trilocular tantalum gauze filled with diced cartilage sutured into position and covering the chest wall defect.

ninth ribs were divided horizontally The medial end of the ninth rib was sutured to the fourth rib in the manner of Mauer and Blades[14] so that they lay diagonally across the cardiac area and served as struts and supports for the tantalum mesh A sheet of tantalum mesh was folded in half and the sides were sutured together with interrupted wire sutures Two similar vertical rows of interrupted wire sutures through both layers of the mesh formed three compartments These were filled with diced bank cartilage The cartilage-filled tantalum mesh was placed on the chest wall defect and molded into shape It was anchored into position with interrupted wire sutures to the fourth and ninth ribs and sternum (See Fig 2) The graft was covered with as much muscle and fascia as could be mobilized The skin was closed with interrupted silk sutures The wound was drained with a catheter to which continuous suction was connected Drainage was moderate the first two days and the catheter was removed on the fourth day Sutures were removed on the seventh day He was discharged on the twenty first postoperative day with a healed wound except for a small granulating area at the medial end He became fully employed in the early part of 1952 and has remained so since

In spite of the maximum efforts to elevate the sternum following a chondrosternoplasty operation for congenital chondrosternal depression or funnel chest there often remains a varying amount of depression in the gladiolar-xiphoid area. In spite of the physiologic relief in elevating the sternum from the compressed heart, patients are so expectant of having a normal-shaped chest that they are keenly disappointed with any degree of depression. In every chondrosternoplasty there remains always a considerable excess amount of pieces of resected costal cartilage. Brodkin[6, 7] has now modified his technique of chondrosternoplasty by dicing these excess pieces of cartilage, deflecting the outer periosteum of the sternum and filling the space with the diced cartilages. The result has been most gratifying, as can be seen in the illustrations (Figs. 3 and 4). Traction with steel wire through the lower end of the sternum was used in this patient.

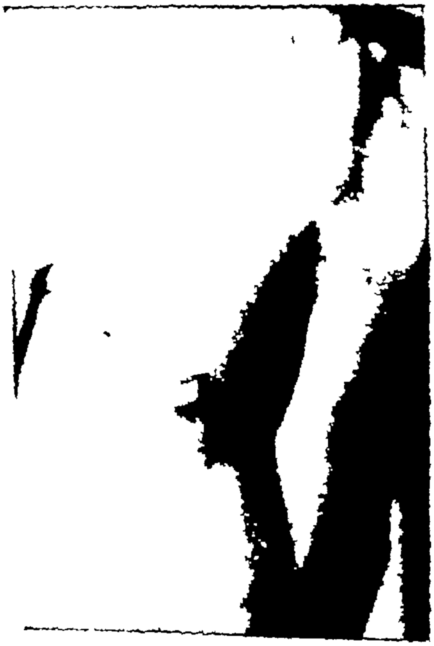

Fig. 3

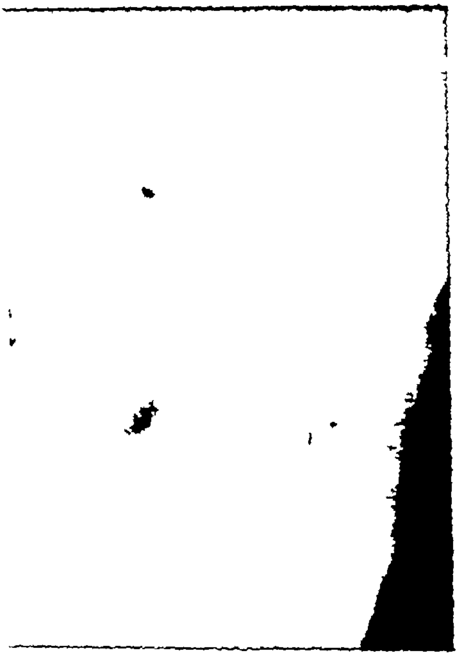

Fig. 4

Fig. 3.—Patient, [illegible], with severe congenital chondrosternal depression (funnel chest). The depression held 140 ml. of fluid.

Fig. 4.—Postoperative view following a chondrosternoplasty in which autogenous diced cartilage was used to fill the residual depression.

Urban and Baker create a chest wall defect after resecting the second to the sixth costal cartilages to remove the internal mammary vessels and lymph node chain during a radical mastectomy for carcinoma in the medial half of the breast. They repair the defect with a free fascia lata graft. To reduce the time of the operation, avoid an additional operative procedure and restore a solid repair of the chest wall, the defect is repaired with a double layer of tantalum gauze between which diced cartilage obtained from the resected cartilage is molded and placed. This can be done by the assistant while the surgeon is dissecting the axilla.

SUMMARY

An additional method is suggested to repair chest wall defects Diced cartilage has proved to be very successful as a graft in places where solid support is necessary It is a very practical replacement, because autogenous cartilage is available, and, when necessary, stored "bank " diced cartilage will prove equally efficacious In large chest wall defects, particularly when protection is desired as in the precordial area a solid wall will be secured with stored diced cartilage In patients undergoing a chondrosternoplasty for congenital chondrosternal depressions (funnel chest), a better cosmetic result will be obtained In the repair of the defect resulting from the resections of the costal cartilages in radical mastectomy, a solid replacement may be obtained by using autogenous diced cartilage and tantalum gauze

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A STUDY OF THE EFFECT OF PARA-AMINOSALICYLIC ACID ON BLOOD COAGULATION AND PROTHROMBIN CONCENTRATION ON PATIENTS WITH TUBERCULOSIS

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THIS study was undertaken to determine whether para-aminosalicylic acid (PAS) as it is ordinarily used in tuberculosis therapy has either a prothrombinopenic effect similar to its analogue, sodium salicylate,[5, 7, 9, 13] or an anticoagulant action caused by the release of heparin from the mast cells as suggested by Soragni,[16, 17] and finally, whether it might in some instances be responsible for serious hemorrhage during the course of thoracic surgery.

LITERATURE

Norvit and Carstensen recently reported, after an extensive study of 400 patients, that PAS had no effect on prothrombin concentration and was never responsible for an increased hemorrhagic tendency.[10] Croizat, on the other hand, reported the case of a 20-year-old white woman with tuberculosis who developed a spontaneous hemorrhage which he attributed to PAS. Her prothrombin concentration was 42 per cent and according to this author was the only reasonable explanation for the hemorrhage.[2] Gordin,[4] Forsgren,[3] Tornaky,[19] Swanson,[15] Barclay,[1] Postiglione,[12] Phillips,[11] and Lynch[6] found that PAS had a small but definite effect upon prothrombin concentration. Several of these investigators expressed the opinion that the effect of PAS on prothrombin concentration was accentuated in patients with liver disease. Soragni reported that although the prothrombin concentration rarely dropped below 60 per cent in adults treated with PAS, children were affected more profoundly. The decrease in prothrombin concentration was independent of the dose given, was not progressive, but showed individual variation and also varied from day to day in the same individual. He found further that the effect was rapidly reversed by administering vitamin K and discontinuing the PAS. He conjectured without experimental evidence that in addition to causing hypoprothrombinemia, PAS might have a further anticoagulant action by releasing heparin from the mast cells.[16, 17]

METHODS AND MATERIALS

The present study consisted of making multiple prothrombin time determinations on eighty-one patients with tuberculosis who were undergoing PAS therapy, with a follow up after PAS had been discontinued on those patients who were found to have developed hypoprothrombinemia. These patients had been receiving 12 Gm. of liquid sodium PAS daily in divided doses for varying periods of time from ten days to over one year. Prothrombin time determinations

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From the Veterans Administration Hospital, Minneapolis, Minn.
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were also made on thirty control patients who had tuberculosis, but had not been on PAS. Second, coagulation time studies were performed on a group of thirty patients with tuberculosis before, and two hours after, a 6 Gm. dose of liquid PAS had been given. Blood levels of PAS were also determined. Last, an attempt was made to determine whether or not there were any instances of abnormal bleeding at surgery or in the immediate postoperative period on the thoracic surgical service at this hospital during the twenty-three-month period from Jan. 1, 1951, to Dec. 1, 1952, that might have been caused by preoperative PAS therapy. During this interval, there had been a total of 288 major thoracic operations performed, including 200 lung resections of various types, forty-two thoracoplasties, seventeen decortications, and twenty-nine miscellaneous procedures. Over 90 per cent of these operations were preceded by a course of PAS and streptomycin.

The prothrombin time determinations were done by the Quick one-stage prothrombin method, using acetone-dehydrated rabbit brain as the source of thromboplastin.[14] Multiple determinations were made on each patient on different days and mean values were used for comparisons. The prothrombin times of normal nontuberculous controls using this method varied from twelve to thirteen seconds.

A modification of the Lee-White method was employed for the coagulation time studies.[13, 14] These were performed as carefully as possible with due attention to the use of scrupulously clean equipment, atraumatic venepunctures, and at controlled temperatures (37° C.). To assure the fact that the PAS administered to the patient had been absorbed, a blood level was obtained at the time of the second coagulation time test approximately two hours after the drug had been taken. For this determination a modification of the Bratton-Marshal sulfonamide assay method was employed.[20]

RESULTS

The results of these various determinations can be summarized as follows: (1) PAS was found to have no demonstrable effect on the coagulation time of blood at concentrations of the drug that were found to average 11.28 mg. per cent. (2) The drug had a slight effect on prothrombin concentration in eleven of the eighty-one patients who were being treated with it. In these eleven patients prothrombin time prolongations varied from 2.8 seconds (55 per cent concentration) to 5.6 seconds (32 per cent concentration). In follow-up studies performed on ten of these patients after PAS had been discontinued all but three had returned to control or very near control values. Of the three patients who failed to return to normal, two had poor liver function but the third had no demonstrable abnormalities, and the etiology of his persistent hypoprothrombinemia was not established.

The effect of discontinuing PAS in the ten patients with prothrombin prolongations is depicted in Fig. 1.

The effect of PAS on the prothrombin time of one of the patients (Patient 5) is shown in Fig. 2. (3) In the third and final portion of this study, it was

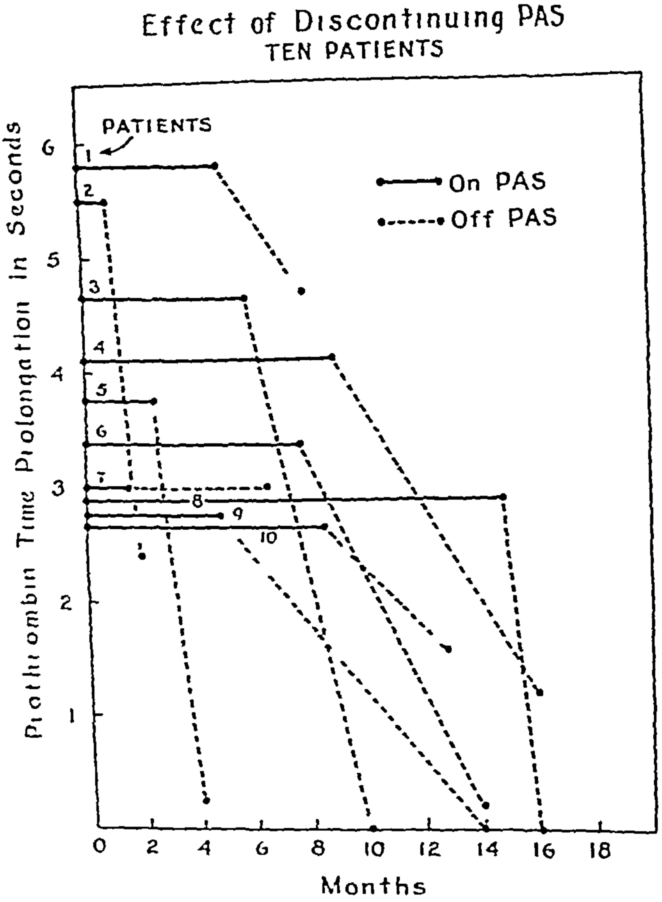

Fig 1—Effect of discontinuing PAS ten patients

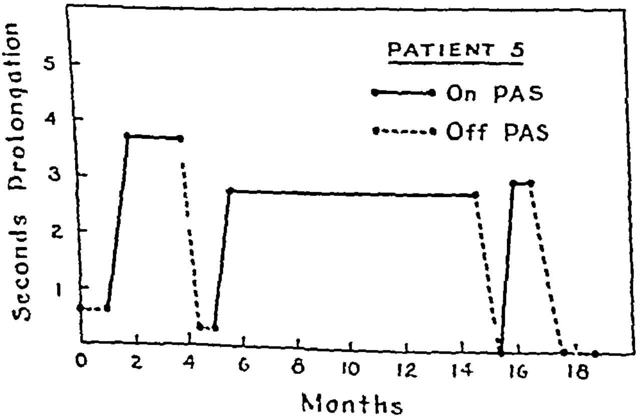

Fig 2—Effect of PAS on prothrombin time prolongation

found that there were no instances of excessive bleeding due to abnormal blood coagulation in the entire group of 288 major thoracic operations during the period under study This observation must be qualified by stating that during the latter half of the period, vitamin K was given to some of the patients who were found to have hypoprothrombinemia Whether any of these would have bled without vitamin K is, of course, not known The absence of abnormal bleeding in this group of surgical operations confirms the impression gained from these experimental data and from most of the literature that the hypoprothrombinemia caused by PAS in a total daily dose of 12 Gm is not of sufficient severity to cause either spontaneous hemorrhage or abnormal hemostasis during the course of surgery

These observations, however, do not preclude the possibility of severe hypoprothrombinemia developing in a patient who for one reason or another might be unusually sensitive to PAS

Because of this possibility, it would be advisable to check the prothrombin concentration of all patients who are receiving PAS one week or so prior to surgery

SUMMARY

An attempt has been made to evaluate the effect of PAS on the prothrombin concentration and coagulation time of blood and, further, to ascertain whether or not this effect is of clinical importance PAS was found to have no discernible effect upon the coagulation time of thirty patients studied A moderate prolongation of the prothrombin time over control values was found in eleven of eighty-one patients studied, these prolongations varied from 2 8 seconds to 5 8 seconds All but three of these prolonged prothrombin times returned to normal values after PAS had been discontinued

There was no clinically evident adverse effect upon blood coagulation, because in 288 surgical procedures, 90 per cent of which were preceded by PAS there were no instances of abnormal hemostasis at the time of surgery or in the immediate postoperative period

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Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty fifth Annual Meeting of the American Association for Thoracic Surgery will be held April 24, 25, and 26, 1955, in Atlantic City, New Jersey Headquarters will be at the Chalfonte Haddon Hall

Requests for Hotel Reservations

These should be mailed directly to Miss Doris Sears, Convention Manager, Chalfonte Haddon Hall, Atlantic City, New Jersey Please mention this Association, the type of accommodation desired, date and approximate hour of arrival If accommodations are desired elsewhere in Atlantic City, please *communicate directly with the hotel of your* choice

Thoracic Surgical Forum

By vote of the membership, the Forum is to be continued for the presentation of short papers on current thoracic research, experimental problems, anatomical studies and modified or new surgical techniques The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves *the right to reject such papers or to suggest their transferral to the regular program* Papers at this session will be limited sharply to ten minutes, including the showing of lantern slides or other illustrative material At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper

These papers will be published together in one issue in the JOURNAL OF THORACIC SURGERY Maximum length 3,000 words without illustrations If illustrated, an appropriate number of words must be subtracted for each cut used

Abstracts for Papers

Abstracts for the presentation of papers at the 1955 meeting, including papers before the Forum, must be received on or before Dec 15, 1954, otherwise they will not be considered by the Program Committee

Abstracts should be labeled "For Thoracic Surgical Forum," or "For Regular Program"

Five repeat five copies of each abstract must be sent to the Secretary of the Association, Dr Paul C Samson, 3959 Happy Valley Road, Lafayette California They should *not* be sent to the Editor

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec 15, 1954, otherwise, the applications will be deferred for consideration until 1956

Applicants must be sponsored by three Active or Senior members of the Association In addition to the signatures on the application form, the sponsors must forward a *separate* letter concerning the applicant directly to Dr Lyman A Brewer, III, Chairman of the Membership Committee, 2010 Wilshire Blvd, Los Angeles 5, Calif

Completed application forms and the sponsoring letters *independently* sent by the three sponsors must be received by Dr Brewer not later than Dec 15 1954, to be considered for action in Atlantic City

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year

The Journal of
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Original Communications

THE OBSCURE PHYSIOLOGY OF POSTSTENOTIC DILATATION: ITS RELATION TO THE DEVELOPMENT OF ANEURYSMS

EMILE HOLMAN, M.D. SAN FRANCISCO, CALIF.

IN THE realm of rheology, the science of flow and elasticity, there exists a curious and puzzling phenomenon known as poststenotic dilatation. Many surgeons have noted it; few have provided an adequate reason for its presence or have ventured an explanation for the mechanism of its development. William S. Halsted was greatly intrigued by it and as usual took the problem to the experimental laboratory where a mild dilatation distal to partial ligation of the terminal aorta was observed in seven of thirty attempts in adult dogs.[1] He suggested that the "abnormal whirlpool-like play of the blood in the relatively dead pocket just below [distal to] the site of the constriction, and the lowered pulse pressure may be the chief factors concerned in the production of the dilation." But he also stated that "it is not denied that the paralysis of the vasomotor nerves and the occlusion of the vasa vasorum may possibly play some part in the manifestation."

Although poststenotic dilatation was first observed and described in the subclavian artery beyond a congenital cervical rib, thoracic surgeons and radiologists have become increasingly familiar with its occurrence in the presence of other congenital abnormalities of the heart and large vessels. Striking is its occurrence beyond a subaortic stenosis as illustrated by the following case.

CASE 1.—A. M. [illegible], aged [illegible], was admitted to Stanford Hospital on Jan. 25, 1953, for study and possible operation upon an aneurysm of the ascending aorta.

His past medical history revealed that ever since infancy he had been told he had a [illegible] that he had not been allowed to play with other children. He had led a fairly normal life except that he had been turned down by the Army because of his heart. In October, 19[illegible], he had been [illegible] with a pain in the right chest which was thought to be [illegible] which promptly subsided on restricted activity. Recent to the 1953 admission [illegible] with some dyspnea, had again sent him to doctors for advice [illegible] diagnosis of an aneurysm of the ascending aorta had been made. His past history [illegible] treatment for syphilis twenty years previously which was said to have been con-

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From the Laboratory for Surgical Research, Stanford University School of Medicine.

Supported in part by the Life Insurance Medical Research Fund.

Read before the Thirty-fourth Annual Meeting of The American Association for Thoracic Surgery, Montreal, Quebec, May 3 to 5, 1954.

genital, since his mother had died of neurosyphilis and his sister had been treated for interstitial keratitis

Physical examination was negative except for a moderate increase in cardiac dullness, a harsh systolic murmur heard best over the right third intercostal space, and a loud aortic second sound with a soft, blowing early diastolic murmur over the left third intercostal space The blood pressure was 135/90, pulse rate 88 Roentgenograms and kymograms (Fig 1) showed uniform dilatation of the ascending aorta with normal pulsation and with no evidence of regurgitation Spinal fluid studies revealed a negative Hinton and a nor

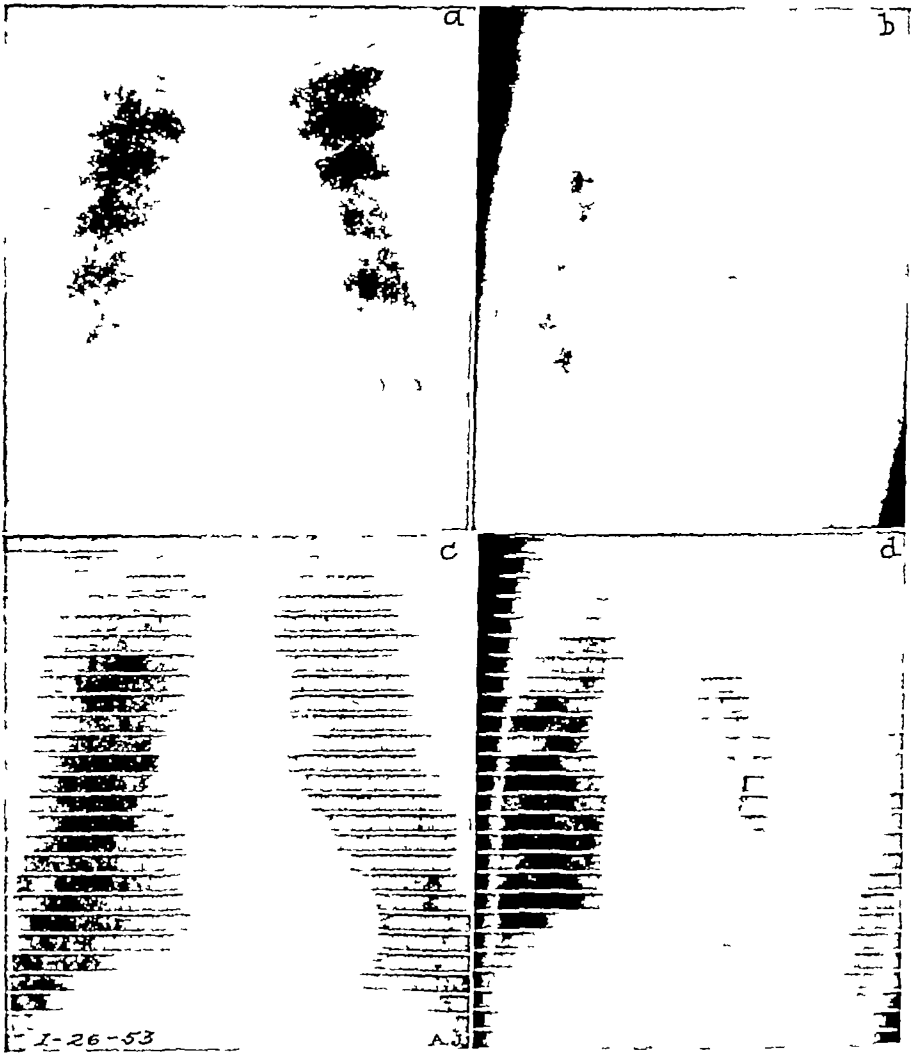

Fig 1 —Case 1 Roentgenograms and kymograms show a markedly dilated ascending aorta originally considered a syphilitic aneurysm However the patient was 43 years old and was known to have had a faulty heart since infancy A diagnosis of congenital subaortic stenosis with poststenotic dilatation was made

mal colloidal gold curve The electrocardiogram was normal. A diagnosis of congenital subaortic stenosis with poststenotic dilatation of the ascending aorta was made He was discharged without operation

A conspicuous and more frequently seen form of poststenotic dilatation occurs distal to a congenital stenosis of the pulmonic valve, of which the following two cases are typical examples

CASE 2—J B was first seen in the Children's Cardiac Clinic on Aug 1 1951, when 4 years old, because of a cardiac murmur noted at birth.

Physical examination revealed a mild mental retardation a loud harsh systolic murmur heard over the entire precordium, maximal over the second left intercostal space, pulse rate 88 blood pressure 112/70, hemoglobin 13 Gm per cent, and 4 800,000 red cells Roentgenograms and angiocardiograms in March, 1953, showed marked prominence and dilatation of the pulmonary artery (Fig 2) Cardiac catheterization disclosed a right ventricular pressure of 98/4 mm Hg and a pulmonary artery pressure of 19/2 mm Hg, with a femoral artery pressure of 96/60 mm Hg Oxygen analyses failed to disclose any evidence of an intracardiac shunt

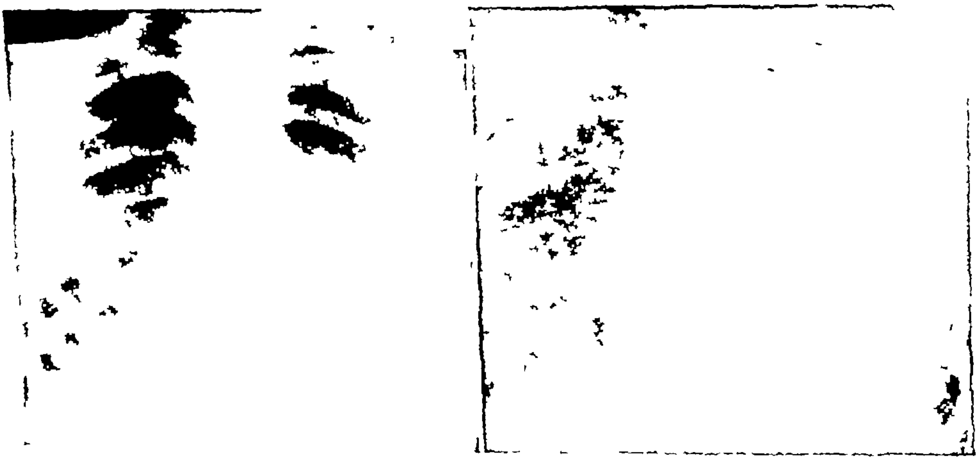

Fig 2—Case 2 J B Roentgenograms and angiograms in a patient aged 6 showed marked prominence of the pulmonary artery At operation a congenital stenosis of the pulmonary valve was found with marked poststenotic dilatation. *A*, Aug 1 1951 *B*, March 19 1953

Because of exercise intolerance (dyspnea and fatigue on running more than twenty yards) and the high right ventricular pressure, the patient was operated upon May 28, 1953 A valvular stenosis was incised and dilated with definite clinical improvement

CASE 3—R W aged 10 was first seen in June, 1949, at age 5, because of a cardiac murmur accidentally discovered two years previously Although he seemed well at the [illegible] admission he had begun to tire easily on exertion associated with the appearance of a circumoral blueness

Physical examination revealed a loud systolic murmur maximal in the second left intercostal space, absent pulmonic second sound, pulse rate 88, blood pressure 100/70, [illegible] femoral pulses [illegible] hematocrit [illegible] hemoglobin 14 Gm per cent, capillary oxygen saturation [illegible] per cent Roentgenograms showed a marked enlargement of the pulmonary artery confirmed by angiograms (Fig 3)

Cardiac catheterization in April, 1951, disclosed a right ventricular pressure of 103/14 mm Hg and a pulmonary artery pressure of 19/13 mm Hg, with a femoral artery pressure of 125/88 mm Hg The catheter passed easily into the left auricle through a patent interauricular septum, but oxygen studies gave no evidence at rest of an intracardiac shunt Because of the high right ventricular pressure, operation was performed and confirmed the presence of a tight valvular stenosis with marked dilatation of the pulmonary artery distal to it

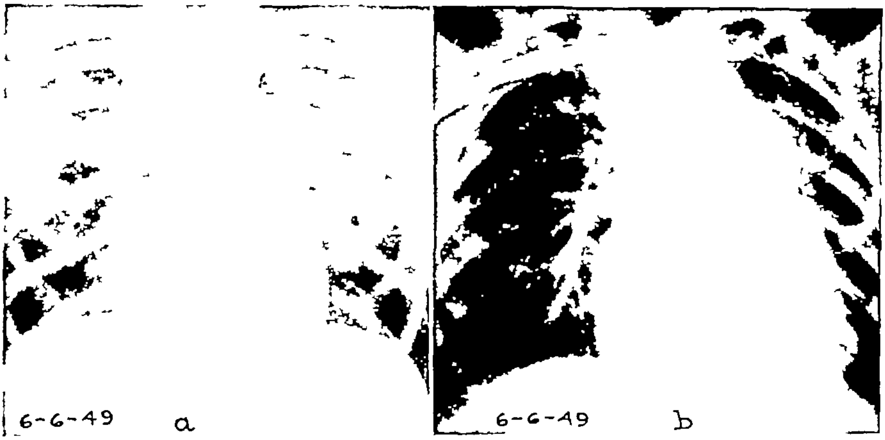

Fig 3 —Case 3 Patient R W Marked prominence of pulmonary artery proved by angiograms and operation to be distal to a tight congenital stenosis of the pulmonic valve

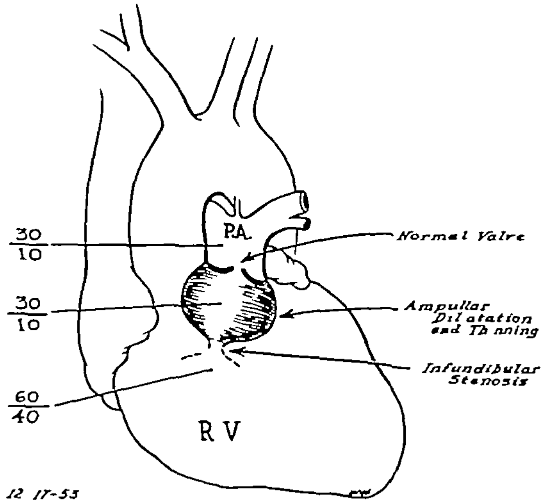

Fig 4 —Case 4 Patient C L. Low infundibular stenosis with normal pulmonary valve does not cause dilatation of pulmonary artery but may cause dilatation of ampulla between the infundibulum and the valve.

In contrast to pulmonic valvular stenosis, the low infundibular stenosis of the pulmonary outflow tract with a normal pulmonary valve is rarely associated with dilatation of the pulmonary artery, but there may occasionally be seen in angiograms, or at operation, a small ampullar dilatation lying between the stenosis and the normal pulmonic valve (Fig 4)

CASE 4 —C L, a 12 year old boy, was first seen at age 7 because of dyspnea, easy fatigability, a cardiac murmur known to have been present since birth, and a history of cyanosis at birth which soon disappeared, but which recurred slightly on exercise

Physical examination disclosed a pale grayish cast to his skin, with questionable cyanosis of lips, pulse rate 84, blood pressure 118/82 mm Hg in the arm 124/77 mm. Hg in the leg a systolic thrill in the second and third intercostal spaces with a loud systolic murmur heard over the whole precordium, but maximal in the left third intercostal space, 6,300,000 red cells, 16 Gm of hemoglobin and a right axis deviation in the electrocardiogram On cardiac catheterization a right ventricular pressure of 170/5 mm. Hg was found, with a pulmonary artery pressure of 19/2 mm Hg and a femoral artery pressure of 110/64 mm Hg There was no evidence of an intracardiac shunt Roentgenograms and angiograms (Fig 5) showed a large right auricle and ventricle and a small pulmonary artery, whose peripheral branches were also small

At operation on Dec 17 1953, an infundibular stenosis was found just distal to which lay a small round knob of poststenotic dilatation proximal to a normal pulmonary valve with normal pulmonary arteries Dilatation and fragmentary removal of some cardiac muscle resulted in limited improvement

Dilatation of the descending aorta beyond a coarctation occurs frequently, although not invariably and may occasionally offer real difficulty in the re-establishment of continuity with the much smaller proximal aorta

CASE 5 —C M was admitted to Stanford Hospital on April 4, 1952, when 3 months old because of coughing spells and difficult breathing

At birth the baby had had a good color and weighed 7 pounds, 8 ounces Within a few days of birth difficult breathing accompanied by a slight but persistent cough was noted When 23 days old she was treated with penicillin because of a presumed bronchopneumonia Temporary improvement was followed by gradual deterioration with increasing symptoms until readmission to the hospital

Physical examination disclosed a poorly developed chronically ill, pale baby, without cyanosis, pulse rate 190, respiration 74, a moderately enlarged heart with a loud systolic murmur heard over the precordium and over the posterior lung fields, slightly palpable femoral pulses, an electrocardiogram that showed right ventricular hypertrophy, 11 7 Gm hemoglobin, 3 75 million red cells, blood pressure 98/70 mm Hg in the right arm, 92/60 mm Hg in the left arm and 58/40 mm Hg in the left leg

A retrograde aortogram through the left brachial artery revealed the presence of a coarctation at the usual site beyond the left subclavian artery (Fig 6) A month after admission the child died with evidence of right upper lobe pneumonitis Autopsy revealed a coarctation and a small interventricular septal defect

Compression of the subclavian artery in the angle between the scalenus anticus muscle and the cervical rib to which it is abnormally attached may also produce moderate aneurysmal dilatation of the artery distal to the stenosis (Fig 7) although the astute W W Keen[3] long dean of American surgeons once expressed wonder that it did not occur proximal to the obstruction William S Halsted[1] abstracted 716 cases of cervical rib recorded in medical literature and in twenty seven cases an enlargement of the subclavian artery fusiform, aneurysmal, or cylindrical, was described He also reported[4] a unique example of acquired poststenotic dilatation following the application of a partially occluding metal band to the innominate artery for the cure of a subclavian aneurysm (Fig 8) Twelve years later the common carotid artery distal to the stenosing band was strikingly dilated throughout its entire length

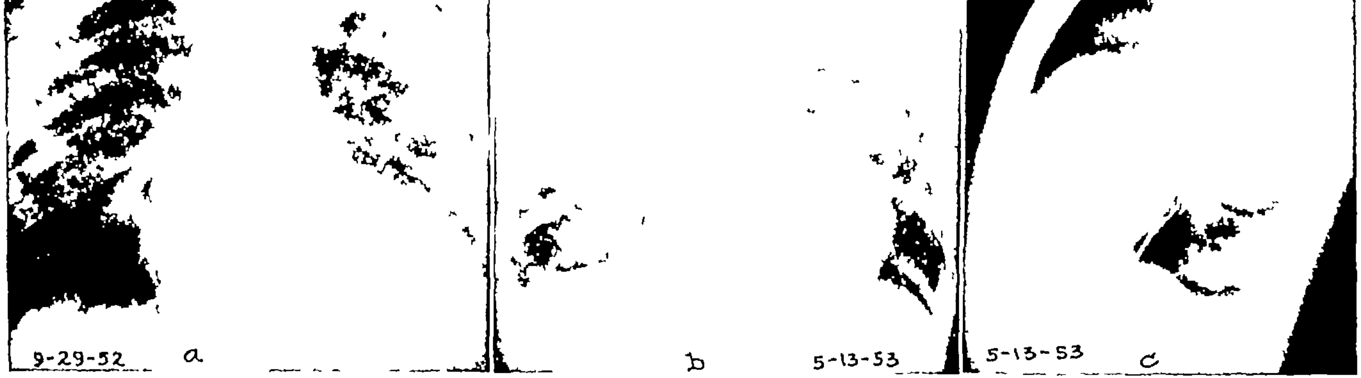

Fig 5.—Case 4 Patient C L Roentgenograms and angiograms confirm absence of dilatation of pulmonary artery in presence of an isolated infundibular stenosis (see Fig 4)

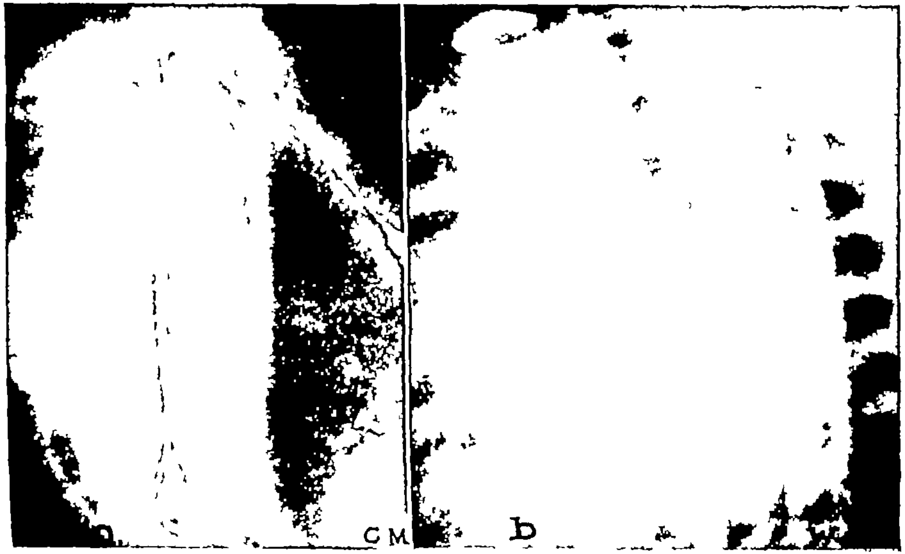

Fig 6.—(a) Aortograms disclose marked dilatation of thoracic aorta beyond a coarctation in a 1 month old infant (b) dilatation in a second 1 month old infant

The most lucid description of the character of poststenotic dilatation as observed at necropsy is contained in a report published in 1869, by Alfred Poland[5] an English surgeon, who noted that "the lining membrane, as well as the middle and external coats of that portion of the artery affected by the swelling were perfectly healthy" and that "there was no atheromatous degeneration of the internal coat nor any thickening of either the middle or external coats" He considered the peculiar lesion "a fusiform dilatation, unaccompanied with any special weakening of any of the three tunics or with any rupture whatsoever "

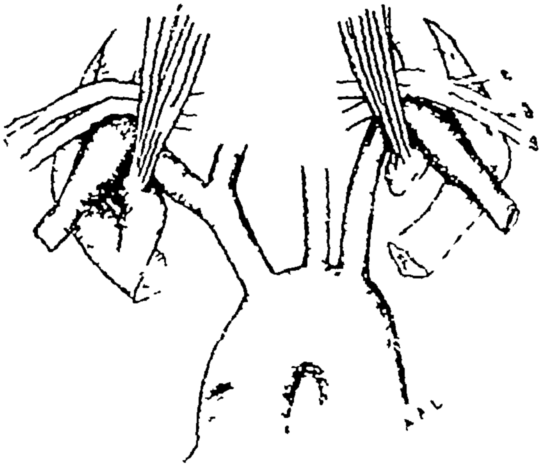

Fig 7—Mild bilateral aneurysmal dilatation of subclavian artery distal to compression of artery by scalenus anticus muscle at site of its attachment to congenitally abnormal cervical rib (Law The Surgical Aspect of Cervical Ribs Journal-Lancet 34 330 1914)

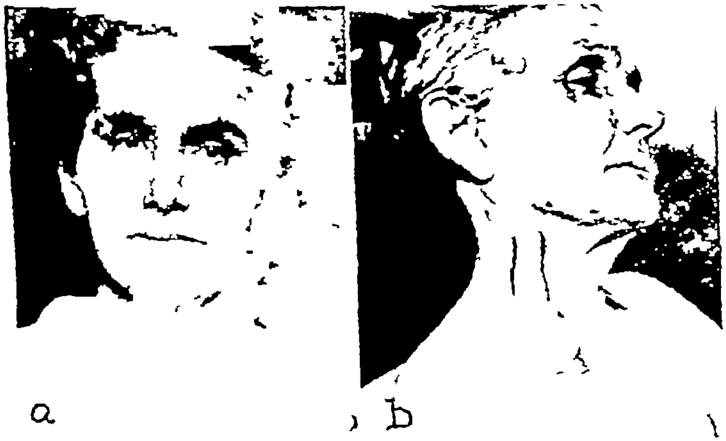

Fig 8—(a) Halsted's case of acquired poststenotic dilatation of right common carotid artery following partial stenosis of innominate artery by metal band for aneurysm of the subclavian artery Aneurysm subsequently cured by ligation of subclavian artery proximal and distal to aneurysm (b) During twelve years of observation the dilatation of the carotid beyond the stenosing band gradually became more pronounced (Surg Gynec & Obst 27 547 1918)

This description of poststenotic dilatation as a fusiform enlargement without disease of the vessel wall conforms in every respect with the character of its occurrence beyond aortic and pulmonic stenoses, and beyond a coarctation of the aorta That it can be reproduced experimentally almost at will has been demonstrated in our laboratory Employing a technique which had previously been found effective in producing pulmonic and aortic stenosis in a study of hemicardiac hypertrophy,[6] Gerbode[7] produced coarctation of the thoracic aorta in 8 day-old puppies by a ligature so placed about the aorta that it did not constrict the lumen, but sharply limited the vessel to its primitive narrow diameter as the rest of the puppy grew to maturity When these animals were killed one or two years later, dilatation beyond the stenosis was invariably present (Fig 9) In our own studies, dilatation was observed eighty-four days following the application of a nonconstricting ligature to the thoracic aorta of three 21-day-old pups, all belonging to the same litter (Fig 10)

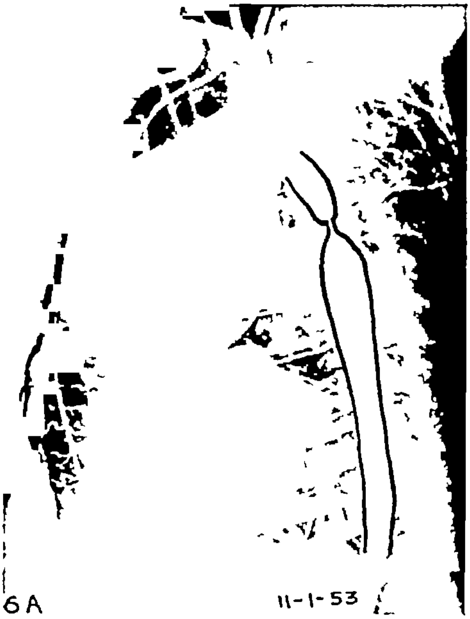

Fig 9 —Post-mortem injection of vascular bed with 17 per cent bismuth oxychloride in a 20 month old dog showed marked dilatation of aorta beyond an experimentally produced coarctation when pup was 8 days old

In the course of studies to develop a method of uniting disparate cylinders,[11] the small left subclavian artery, with a diameter of 4 mm , in a 14-day-old puppy was joined to the distal end of the divided thoracic aorta, whose lumen measured 8 mm in diameter, by the so called Y plasty In one instance, poststenotic dilatation immediately distal to the anastomosis appeared within twenty-four days, and in a second puppy, it was demonstrated by an aortogram at the end of ten weeks (Fig 11) These two experiments demonstrated that

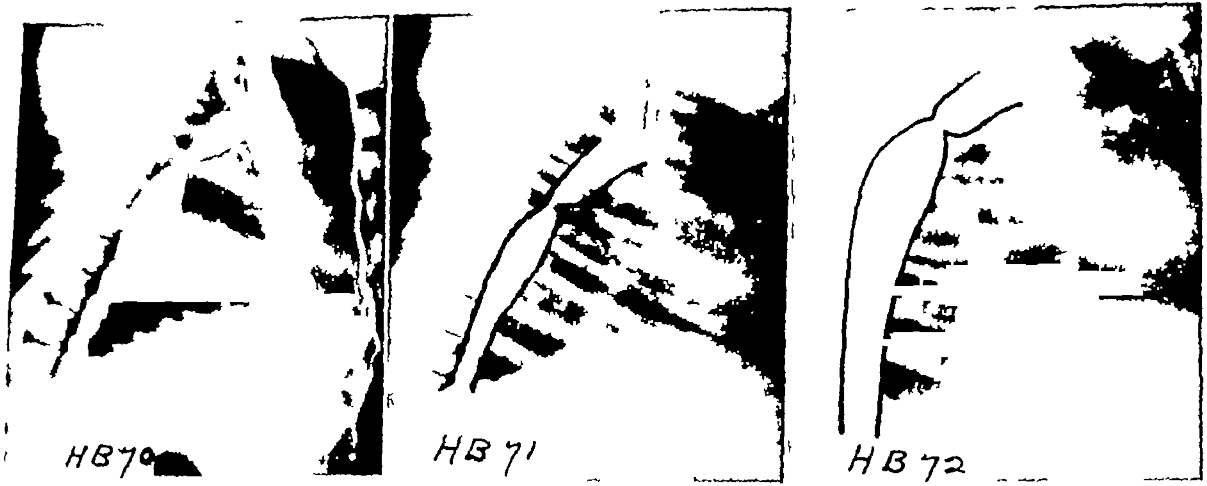

Fig 10 —Dilatation beyond a coarcting ligature applied to the thoracic aorta was invariable as illustrated in three pups from the same litter operated upon eighty-four days previously

when a stream of small caliber suddenly flows into a vessel of larger diameter, the same hydraulic forces come into play as are found beyond an abrupt partial stenosis.

Experiments were then conducted with an artificial circulatory system (Fig. 12) which included a pump whose rate varied from 84 to 120 pulsations

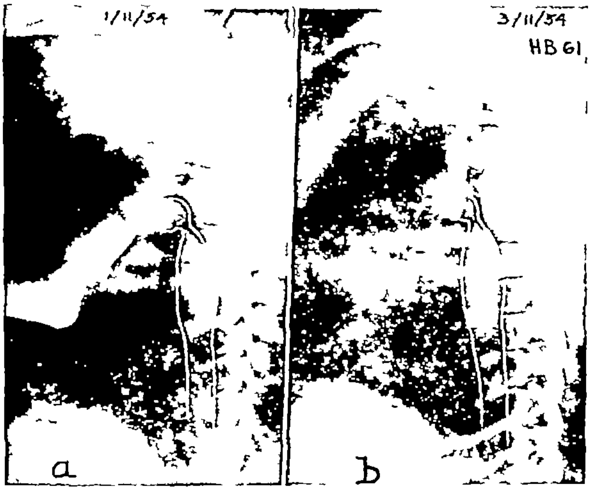

Fig. 11.—Aortograms disclosed progressive dilatation beyond end-to-end anastomosis of subclavian artery to distal end of divided thoracic aorta (a) ten weeks and (b) eighteen weeks after operation.

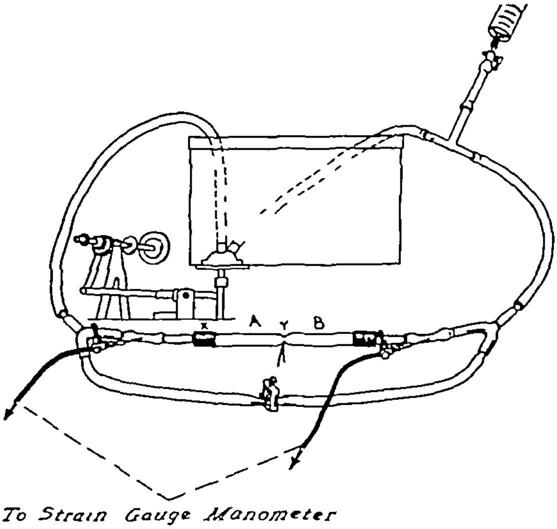

Fig. 12.—Schematic drawing of pump and conduits simulating the circulation with a segment of elastic rubber tubing introduced into system with constrictions at X and Y; capacity of system about 200 c.c. water.

per minute and whose stroke output varied from 1.7 c.c. to 9.7 c.c. The conduits consisted of rigid plastic tubing with an internal diameter of 0.6 cm., but included also a segment of elastic rubber tubing whose wall had an average

TABLE I

PRESSURE IN SYSTEM	STROKE		DIAMETER OF MAXIMUM POSTSTENOTIC DILATATION (CM.)	LENGTH OF POSTSTENOTIC DILATATION (CM.)
	RATE	OUTPUT (C.C.)		
120/70	96	5.7	2.0	1
	8 c.c. water added to system			
125/80	96	5.7	2.8	3
	Stroke output increased to 9.8 c.c.			
160/80	96	9.8	3.0	4
	Stroke output decreased to 5.7 c.c.			
125/80	96	5.7	2.5	2.5
	8 c.c. water added to system			
125/75	96	5.7	3.2	3.5
	Stroke output increased to 9.8 c.c.			
145/60	96	9.8	3.4	3.5

Capacity of circulatory system 200 c.c.

thickness of 0.033 cm. and whose internal diameter was 1.6 cm. The pressure in the system could be varied by increasing or decreasing the volume of circulating fluid and the velocity of flow was varied by altering the stroke output. Table I records the effect upon the elastic segment of varying the pressure and the velocity of flow in the system.

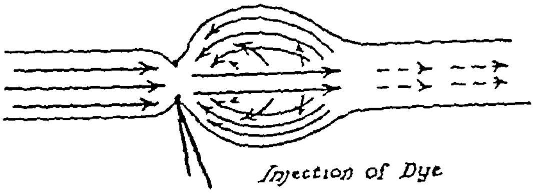

Fig. 13.—When dye is injected proximal to a constriction remarkable eddies of turbulent and reversed flow are noted just distal to the stenosis where the rapidly ejected stream strikes the more slowly flowing and stagnant distal stream and where high kinetic energy is transformed into high potential energy or lateral pressure.

In another experiment, the volume of circulating fluid was increased sufficiently to produce a mild poststenotic dilatation. The stroke output was then gradually reduced from 9.8 c.c. to 7.2 c.c., at which point the poststenotic dilatation disappeared. Restoring the stroke output to 9.8 c.c. caused the poststenotic dilatation to recur.

When a concentrated solution of methylene blue was injected into the lumen beyond the constriction the dye promptly disappeared without delay into the fast flowing distal stream. However, when the dye was injected proximal to the stenosis there was noted just distal to the constriction a definite delay in its progress downstream (Fig. 13). It appeared to be involved in turbulent eddies before it hesitatingly resumed its forward flow. It was even seen to reverse its direction and to flow backward momentarily, toward the stenosis. The site of delay and of turbulence of flow was identical with the site of dilatation as well as with the location of the palpable thrill and audible bruit. Similar observations were made repeatedly.

The following experiment provided a completely convincing demonstration that the play of hydraulic forces against the elastic wall just beyond a stenosis will, in time, produce poststenotic dilatation

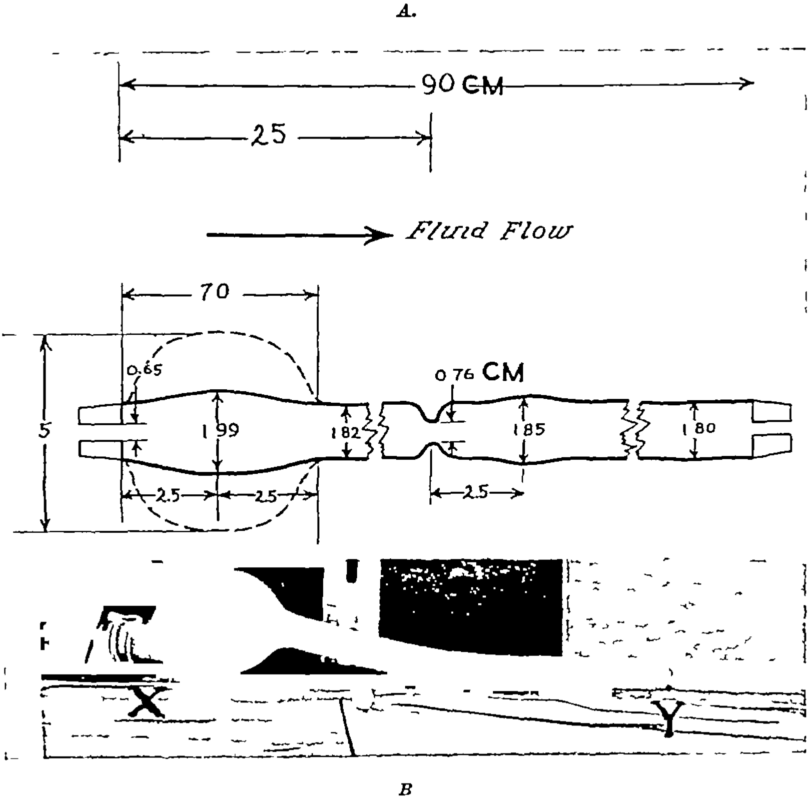

Fig 14 —A 90 cm long segment of rubber tubing 1 8 cm in diameter with two points of constriction was subjected to twenty-one hours of continuous pumping at which time mild dilatation appeared beyond both constrictions After eleven more hours of continuous pumping during which time there was no change in the mild dilatation the tubing suddenly ballooned out beyond the first constriction to a diameter of 5 cm over an area about 7 cm. long This alteration was permanent and represents maximal structural fatigue at site of greatest lateral stress

Into the artificial circulatory system was inserted a segment of elastic tubing 90 cm long and 1 8 cm in diameter (Fig 14) Twenty-five centimeters beyond the junction of the rigid tubing with the elastic tubing, a second site of stenosis was produced by partial ligation, which reduced the diameter of the tubing to about 0 75 cm Enough water was introduced into the system to distend the elastic tubing to a normal and uniform diameter throughout, without dilatation beyond either constriction The pump was set at 84 pulsations per minute with an output per stroke of 9 8 c c

After twenty-one hours of continuous pumping without the slightest evidence of dilatation, there began to appear definite but mild dilatation beyond the first constriction, with an even milder dilatation beyond the second constriction At this time the pulsations were increased to 120 per minute Ten more hours of continuous pumping produced no significant change in the dilatation beyond either site of constriction Suddenly, however, after thirty-one hours of pumping and after eleven hours of mild dilatation, there occurred a remarkable aneurysmal dilatation just beyond the first constriction An outside diameter of 2 cm was suddenly increased to 5 cm , and the poststenotic dilatation was now 7 cm long (Fig 14, *B*) Moreover, the dilatation was now permanent, whether the pump worked or not The elastic tubing had yielded suddenly and irrevocably to the play of hydraulic pressures just beyond the stenosis Previously the mild dilatation had promptly subsided when the pumping ceased With the appearance of the balloonlike dilatation beyond the first constriction, the dilatation beyond the second constriction disappeared completely because of the dissipation of pressure and pooling of fluid from the rest of the small system in this excessively dilated area

In another experiment, a second 90 cm length of rubber tubing with two points of stenosis was subjected to the continuous operation of the pump (Fig 15, *a*) After about ninety hours of pumping, mild dilatation appeared just beyond the first constriction (Fig 15, *b*), which subsided when the pumping ceased (Fig 15, *c*) By applying the abrasive action of sandpaper, the wall of the tubing 2 cm beyond the constriction was slightly thinned out, resulting in a small pouchlike dilatation at this weakened area when the pumping was resumed The pressure in the system was then increased by the addition of only 5 c c of water Instantly there occurred an accentuation of the pouchlike protrusion, followed gradually by a balloonlike dilatation of the tube just beyond the stenosis When the pump was stopped, the aneurysmal dilatation disappeared The effectiveness of the play of hydraulic forces in producing an aneurysmal dilatation immediately beyond a site of constriction was vividly portrayed before our almost incredulous eyes

In another illuminating experiment, a segment of the small intestine of a cat was introduced into the circulatory system in place of the rubber tubing After about eighteen hours of pumping first the circular and longitudinal musculature split and then the fibrous submucosa burst 3 cm beyond the junction of the small rigid tubing and the larger distensible intestinal lumen, the rent extending for about 2 cm

These various observations of the effects of a stenosis in an artificial circulatory system demonstrated conclusively that poststenotic dilatation was the direct result of the play of hydraulic forces set in motion by the stenosis and that it varied in degree with the pressure and velocity with which fluid was ejected from the stenotic channel Moreover there appeared to be a critical level of pressure and of velocity below which poststenotic dilatation did not occur The element of time was most important, dilatation appearing in one experiment only after the play of hydraulic forces had persisted for a prolonged period thirty one hours in one experiment and ninety hours in a second experiment It is quite evident that other important factors may determine the duration of the play of hydraulic stresses and strains necessary before dilatation occurs These are the inherent resistance of the vessel wall to dilatation, depending upon its structural qualities, the relationship between the elasticity of the wall and the pressure and velocity of flow to which it is subjected, the degree of stenosis present, and perhaps the viscosity of the circulating fluid It appears that unless the stenosis reduces the lumen to one-third or one-fourth its original diameter, turbulence of flow will be minimal and only minor dilatation will occur, and may be long delayed

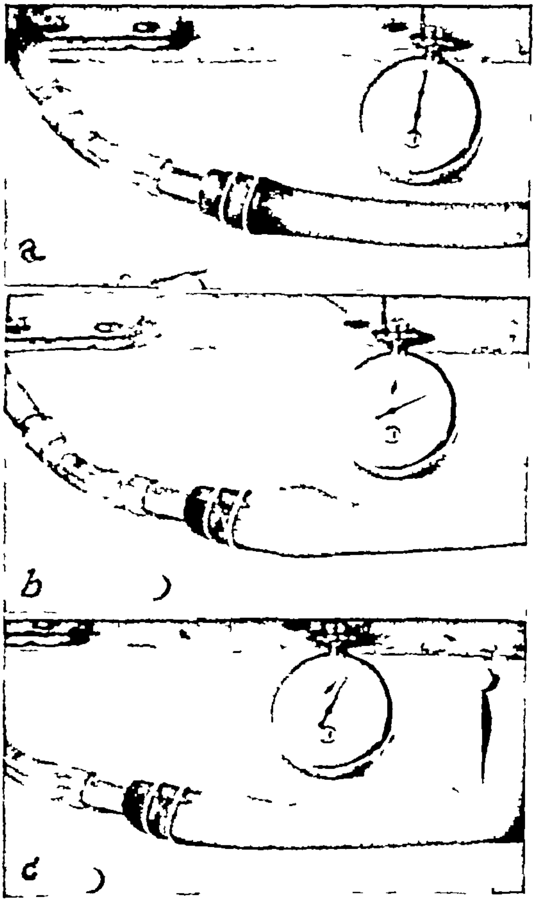

Fig 15—(a) Appearance of rubber tubing at beginning of experiment showing complete absence of dilatation beyond constriction despite pumping action

(b) Postconstriction dilatation appeared after ninety hours of continuous pumping

(c) Dilatation disappears promptly but not completely when pumping ceases Incomplete disappearance due to permanent alteration as the result of structural fatigue

In reviewing these experimental observations with due regard to certain principles of hydraulics, as emphasized by Professor John K Vennard[8] of the Department of Civil Engineering at Stanford University, certain causes and effects were postulated as operating beyond a narrow stenosis in a large vessel transporting blood under relatively high pressure and high velocity

During diastole in a pulsating system, there occurs normally a momentary retardation in flow which is markedly accentuated just beyond a stenosis During systole, there emerges from the narrow stenotic channel a stream of blood at a greatly increased velocity, as compared with the velocity in the broader channel either proximal or distal to the stenosis Mathematically, the velocity of flow, other factors remaining the same, is inversely proportional to the square of the radius Obviously, if a tube 18 mm in diameter is suddenly reduced to a diameter of 6 mm, the velocity through the constriction is increased nine times Conversely, if a tube 6 mm in diameter is suddenly increased to a diameter of 18 mm, the velocity will be reduced to one-ninth its previous rate The rapidly ejected stream runs head on as it were, into the more slowly flowing, and relatively stagnant, poststenotic stream, resulting in a sudden retardation in its forward flow High kinetic energy is suddenly converted into high potential energy or lateral pressure Moreover, the sudden arrest of the rapid stream produces eddies of turbulent and reversed flow, which strike the elastic vessel wall with alternating high- and low-pressure waves causing the wall to vibrate these vibrations being recognizable as a palpable thrill and an audible bruit The location of maximal clash of streams and of the site of conversion of high kinetic energy into high lateral pressure and therefore also the zone of greatest turbulence, lies about 1 to 3 cm beyond the constriction, depending upon the caliber of the conduit, and upon the pressure and velocity of flow At this point, also, the maximal dilatation occurs

A factor supremely important to the hydraulic expert concerns the phenomenon of structural fatigue Unevenly distributed in the zone of turbulent flow are impacts or shocks of increased pressure alternating with decreased pressure which produce points or minute areas of high local stress against the limiting vessel wall Depending upon the pressure in the system, the velocity of flow, and the structural qualities of the vessel wall, this oscillation of high and low pressures against the individual fibers of the vessel wall results in the prompt or very gradual onset of structural fatigue and in a potential thinning or distention of the wall at these points of impact As these points of shock or stress vary in position from moment to moment and are diffusely distributed in diminishing vigor throughout the zone of increased lateral pressure the sites of structural fatigue are correspondingly diffusely distributed in diminishing severity, resulting in a tapering dilatation of the vessel wall

The absence of dilatation proximal to the constriction is dependent upon the concept that the pressures are evenly and uniformly distributed against the limiting vessel wall and since the forward flow here is not subjected to sudden retardation or arrest there is no conversion of kinetic energy into lateral pressure General pressure proximal to the stenosis may be higher than the pressure distal to it but it is a relatively uniform level of pulsatile pressure evenly distributed throughout and not subject to the rapidly oscillating variations in localized pressure such as occur in the turbulent flow produced by the clash of streams distal to the stenosis As a result of this uniform distribution of pressure proximal to the stenosis, uniform expansion of the vessel occurs with each pulsation

In analyzing further the play of hydraulic forces distal to a stenosis, it appears that there are three factors operating here to produce greater dilatation of the vessel The first factor is the sudden conversion of high kinetic energy into high potential energy or lateral stress The second factor is the turbulence of flow due to a clash of streams of differing velocities, which causes eddies of alternating high and low pressures to strike against the elastic wall The third factor is the lowered velocity due to the widening of the stream diameter produced by the first two factors According to the Bernoulli principle, this lowered velocity will of itself increase lateral pressure In a pulsating stream, the first two factors recur repeatedly with each systole and set the stage, as it were, for the third factor to act, also in repetitive manner The result of these three inexorably recurring influences in a pulsating stream, operating in a localized segment of an elastic distensible vessel, is a vicious circle greater lateral pressure → greater widening of the stream-diameter → lessened velocity of flow → greater lateral pressure → greater widening of the stream diameter → lessened velocity of flow, and so forth Insidiously progressive dilatation is an inevitable result unless the resistance to further dilatation inherent in the intact vessel wall itself or the incompressibility of the surrounding structures prevent it Even these conditions may not prevent it, so effective and insistent are these hydraulic forces, given sufficient time

Certain clinical observations confirm the great importance of the height of pressure and velocity of flow in the development of poststenotic dilatation (Fig 16) It occurs most prominently in the ascending aorta beyond a subaortic stenosis where the left ventricle ejects blood under maximal pressure, at maximal velocity, in maximal mass, against a maximal peripheral resistance It is almost equally prominent beyond a stenosis of the pulmonic valve where the hypertrophied right ventricle ejects an equally large mass of blood under high pressure and at high velocity It is less prominent beyond a coarctation of the aorta since the pulsatile end pressure here is less than in the ascending aorta, the distal peripheral resistance is less, and the mass of blood forced through the coarctation and the resulting velocity of its flow have been reduced significantly by the escape of blood through the large branches of the aortic arch Its moderate development in the subclavian artery beyond a cervical rib is also related to the lower pressure in this smaller vessel with lessened peripheral resistance beyond it Its apparent absence beyond constrictions in vessels of still smaller caliber is related to the lower pressure and lower velocity as one approaches the periphery, where the disparity between systolic and diastolic pressures is gradually being reduced and where pulsatile flow gradually changes to more uniform and even flow Such observations indicate that the occurrence and degree of dilatation depend upon the height of systolic pressure with which blood is thrust against the constriction, which in turn determines the velocity of flow with which blood is ejected from the short stenotic channel The greater this velocity, the more distantly distributed

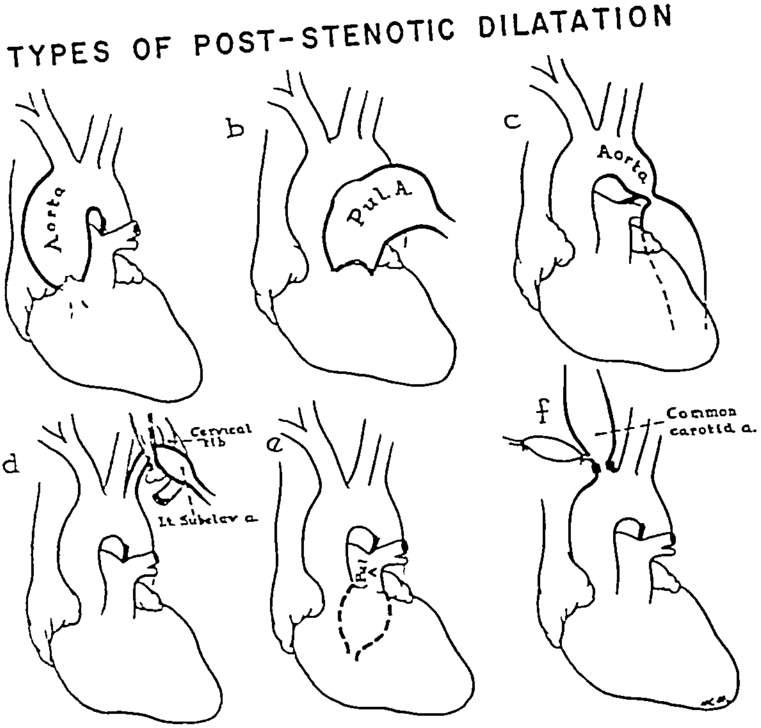

Fig. 16.—Poststenotic dilatation is most pronounced beyond a subaortic stenosis, equally prominent beyond a pulmonic stenosis, less developed beyond a coarctation of the aorta, mildly present distal to compression of the subclavian artery between the scalenus anticus muscle and its attachment to a cervical rib, occasionally present in the small ampulla between an infundibular stenosis and the pulmonic valve and in a unique instance it occurred distal to a partially occluding band applied to the innominate artery. The degree of poststenotic dilatation is intimately dependent upon height of pressure and upon velocity of flow.

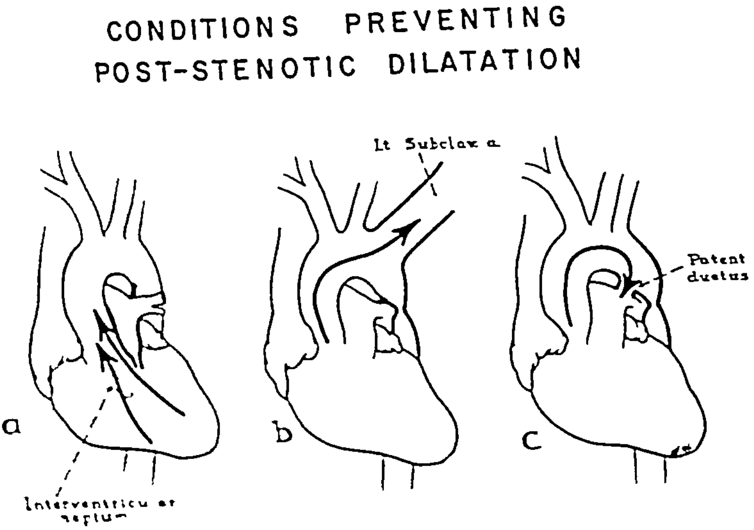

Fig. 17.—Conditions which prevent dilatation beyond a stenosis: (a) an interventricular septal defect [illegible] diversion of blood away from the pulmonary artery [illegible] velocity of flow through the accompanying infundibular stenosis; (b) [illegible] subclavian artery may divert a large volume of blood [illegible] thus preventing dilatation beyond the coarctation; (c) a [illegible] effectively diverts a volume of blood away from the [illegible] to prevent dilatation of the aorta beyond the coarctation.

are the impacts of the swiftly flowing systolic stream against the momentarily retarded distal diastolic stream and, therefore, the more distantly effective are the shocks of increased lateral pressure against the vessel wall

Other clinical conditions have been observed which prevent the development of poststenotic dilatation or determine its degree (Fig 17) Most importantly, the volume of blood forced through the constricted channel and, therefore, the velocity of flow with which the blood is ejected from the stenosis may be greatly altered by conditions just proximal to the stenosis a large collateral channel such as a greatly dilated left subclavian artery may reduce the volume flow through a coarctation, an open ductus located just proximal to a coarctation may drain a large volume of blood into the pulmonary artery away from the coarctation, an interventricular septal defect and an overriding aorta as in the tetralogy of Fallot may provide a large "runoff," or diversion, of blood away from the infundibular stenosis, thus reducing markedly the mass and the velocity of blood flow through the stenosis

The difficulty encountered by Halsted and Reid in their experimental attempts to produce postconstriction dilatation by partial ligation of the terminal abdominal aorta may be due to the diversion of blood away from the site of partial ligation through the many large branches just proximal to it, such as the celiac axis, the two large renal arteries, the inferior mesenteric artery, and the several paired lumbar vessels These can effectively reduce both the velocity and pressure with which blood is ejected through a stenotic channel produced in the terminal aorta and thus prevent or greatly curtail poststenotic dilatation In our experiments, when the coarctation was produced in the thoracic aorta, where pulsatile pressure, velocity of flow, and mass of blood thrust against the construction are higher than in the terminal aorta, dilatation beyond the coarctation invariably occurred

That a runoff or diversion of flow away from the stenosis may effectively prevent poststenotic dilatation was convincingly demonstrated by the following case of a large patent ductus proximal to a coarctation of the aorta

CASE 6—K B, aged 10,* was admitted to Stanford Hospital in January, 1954, for correction of a coarctation of the aorta accompanied by a patent ductus, both of which had been recognized soon after birth There was no history of cyanosis

Physical examination disclosed a very pale but well developed normal child except for a loud continuous murmur at the left cardiac base with a loud pulmonic second sound, heart definitely enlarged and hyperactive (Fig 18), pulse rate 98, hemoglobin 13 Gm per cent, hematocrit 39, 4,250 white cells, urine normal, blood pressure right arm 142/90 58 mm Hg, left arm 140/92 60, no pressure obtainable in either leg, after the patient spent two days in bed, blood pressure in the arm dropped to 128/70 56

At operation, a widely open ductus arteriosus, 8 mm in diameter, was found, transmitting blood from the aorta to the pulmonary artery Just distal to this open ductus lay a typical coarctation, but the caliber of the aorta distal to it was diminished rather than increased The aorta proximal to the constriction had a diameter of 1 7 cm, and the distal aorta a diameter of 1 3 cm (Fig 19) The coarctation itself had an inner lumen of about 3 mm in diameter To re establish continuity of the two disparate ends, the small distal aorta was incised longitudinally for about 7 mm in its anterior half, thus providing the necessary extra circumference for satisfactory suture to the larger proximal aorta. As a result of this V plasty, the lumen of the anastomosis exceeded the lumen of the smaller vessel and there was no constriction at the site of union.

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*A patient of Dr Ann Purdy

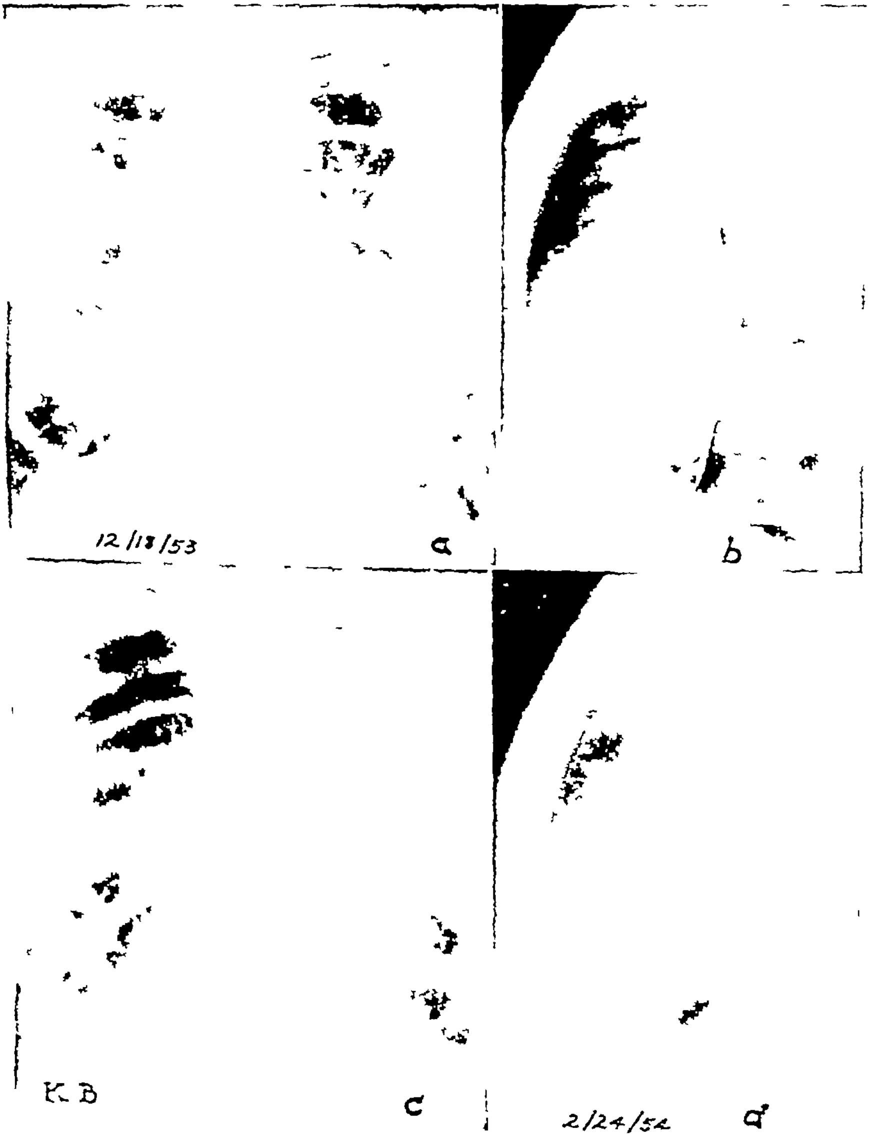

Fig. 18.—Roentgenograms (a and b) of a 10 year old child before excision of a coarctation and ligation of a patent ductus proximal to the coarctation showed a marked dilatation of the heart which subsided promptly following operation (c and d) (see Fig 19)

When the flow through the aorta was reestablished by removing the occluding [illegible] in the right arm dropped from 170/110 to 120/90, and the conditions in the [illegible] and distal to the anastomosis were promptly reversed [illegible] the proximal [illegible] smaller than the aorta distal to the anastomosis! Good pulses could now be felt in both feet and on leaving the hospital ten days later, the pressure [illegible] was 12[illegible] and in the right leg 132/96 mm Hg

The absence of dilatation beyond the coarctation in this instance was the direct result of the diversion of a large volume of blood through the patent ductus into the pulmonary artery which reduced markedly the pressure and velocity of blood flow through the coarctation

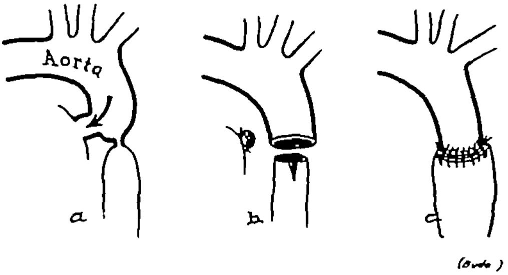

Fig 19—(*a*) Dilatation beyond a coarctation does not occur in the presence of a large open ductus proximal to the coarctation which diverts blood flow away from the stenosis

(*b*) Anastomosis of disparate ends effected by use of V-plasty to avoid stenosis at site of union

(*c*) Note larger diameter of distal aorta as compared with proximal aorta after elimination of ductus and excision of coarctation

In the tetralogy of Fallot, in which the interventricular septal defect and the overriding aorta provide channels through which blood from the right ventricle is diverted away from the pulmonary outflow tract, no dilatation of the pulmonary artery is observed On the contrary, in a tetralogy the caliber of the pulmonary artery and its two main branches is usually greatly diminished, commensurate with the reduced volume flow of blood through these channels When the pulmonary artery and its branches are found to be dilated, one would suspect that the interventricular septal defect is small and that the stenosis involves the pulmonary valve rather than the infundibulum

In the presence of pure pulmonic stenosis, without intracardiac shunts, the absence of dilatation of the pulmonary outflow tract as disclosed by roentgenograms of the chest strongly favors an infundibular stenosis On the other hand, a dilated pulmonary artery as disclosed by roentgenograms in the presence of a presumed pure pulmonic stenosis is suggestive evidence that a valvular and not an infundibular stenosis is present (Fig 20)

CASE 7—W M, aged 33, entered Stanford University Hospital in January, 1954, for possible operation upon a presumed patent ductus He had a murmur over the heart which he believed had been present from birth, and certainly from the age of 12 He had been barred from high school football because of his heart, and had been turned down for military duty by the draft board on a cardiac disability Recent to admission he had become more easily fatigued, associated, on excessive activity, with a dry nonproductive cough and discomfort in the chest He disclaimed exertional dyspnea, ankle edema, cyanosis, or orthopnea

Physical examination revealed no cyanosis, nor clubbing of the fingers, pulse rate 82, loud systolic murmur maximal in left first and second intercostal spaces, pulmonic second sound split with loud second component blood pressure 130/74, good femoral pulses, hemoglobin 15 8 Gm per cent, hematocrit 48, 7,100 white cells, right axis deviation, with conduction defect Plain roentgenograms showed a marked prominence in the left hilar area which was identified by *angiocardiography as dilatation of the pulmonary artery*

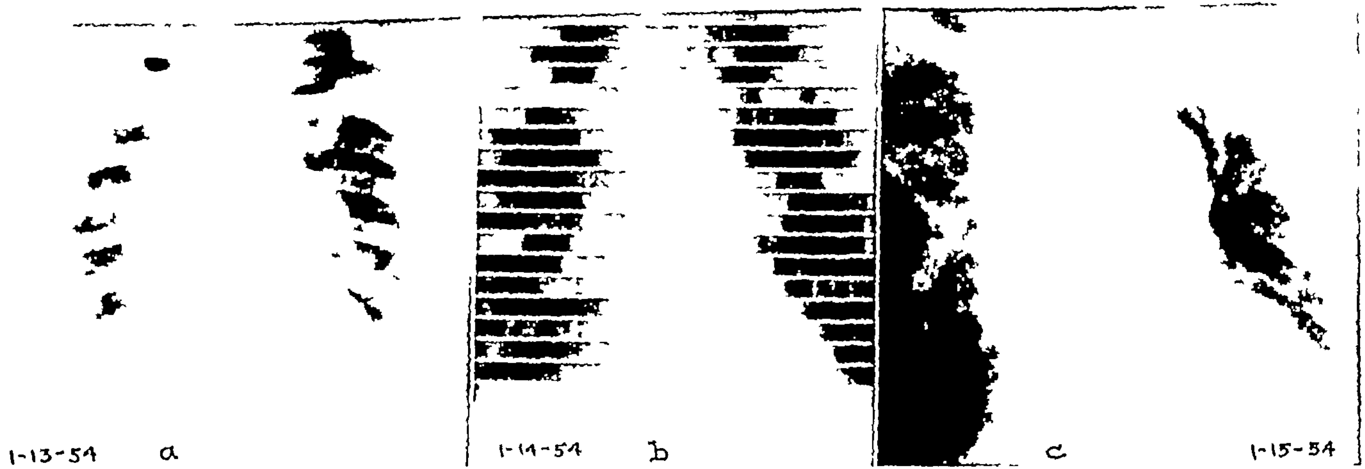

Fig. 20.—Case 7. Patient W. M. When roentgenograms in the presence of a presumed pure pulmonic stenosis without intracardiac shunts reveal marked dilatation of the pulmonary artery it is presumptive evidence of a stenosis of the pulmonic valve rather than of the infundibulum.

(Fig 20) A significant observation in the angiograms was the pronounced delay in the emptying of the poststenotic dilatation dye which normally should leave this area in 3 seconds provided opacification of the dilated vessel for 4½ to 5½ seconds, a phenomenon also observed in our experimental studies of the flow distal to a constriction Cardiac catheterization disclosed a pressure of 39/5 mm Hg in the right ventricle, and a pressure of 19/7 mm Hg in the pulmonary artery, and no evidence at rest of an intracardiac shunt

A diagnosis was made of an isolated pulmonic valve stenosis without intracardiac shunt and only moderate right ventricular pressure No immediate surgical treatment was advised, but the patient was requested to return for cardiac catheterization in one year's time to determine whether any increase in right ventricular pressure had occurred If so, surgery would be indicated

These experimental and clinical observations remove all doubts as to the cause of the poststenotic dilatation—it is not biologic, nor supernatural, it is not due to disruption of sympathetic nerves, nor to vasomotor paralysis, it is not the result of occlusion of the vasa vasorum nor of localized impairment of circulation, it is not the result of external trauma nor of an unusually well-developed collateral circulation entering the vessel distal to the coarctation, it is not the result of a dead pocket, nor of stagnation of fluid in this pocket It is the simple, mechanical effect of the operation of natural hydraulic laws that govern the flow of fluid through a conduit—in this instance not a rigid walled conduit, but an elastic vessel, capable of distention in response to increased lateral stresses repeatedly applied over a prolonged period of time

These observations also carry other wide implications They are strongly suggestive that the initiating factor in the development of the arteriosclerotic aneurysm may be occasionally a stenosis of the arterial lumen imposed by a segmental atherosclerosis, through which a narrowed stream flows with increased velocity into a still normally distensible distal segment, thus setting the stage for the play of hydraulic forces capable of producing a localized aneurysmal dilatation of the vessel (Fig 21, *a*) If there is a limited area of pronounced localized weakening of the wall in the segment just beyond the stenosis, where the play of hydraulic forces is greatest, a linear rupture may occur, resulting in the initiation of a dissecting aneurysm (Fig 20, *c*) Or a localized weakened area in the vessel wall may yield gradually to the play of hydraulic pressures, resulting in a sacculated aneurysm distal to the stenosis (Fig 20, *b*)

Once a dilatation has been initiated, the process is perpetuated and enhanced through the application of the principle that a widened lumen slows the stream, a slowing of the stream increases lateral pressure (the Bernoulli principle), and increasing lateral pressure further dilates the vessel, thus setting up a vicious circle which is limited only by the inelasticity and rigidity of the vessel wall or by the incompressibility of surrounding structures In reality, the play of these hydraulic forces may prove at times irresistibly destructive, as evidenced by the inexorable dilatation of an aneurysm against such seemingly incompressible or indestructible substances as bone Through the operation of the phenomenon of structural fatigue and by the processes of compression, interference with blood supply, and consequent absorption, even the bodies of vertebrae may gradually be worn away The progressive thinning of the elastic vessel wall itself, once the dilatation has been initiated, is an additional important factor in its progressive dilatation by reducing progressively its resistance to the play of these hydraulic forces The progressive nature of an aneurysmal dilatation once initiated is thus more easily understood

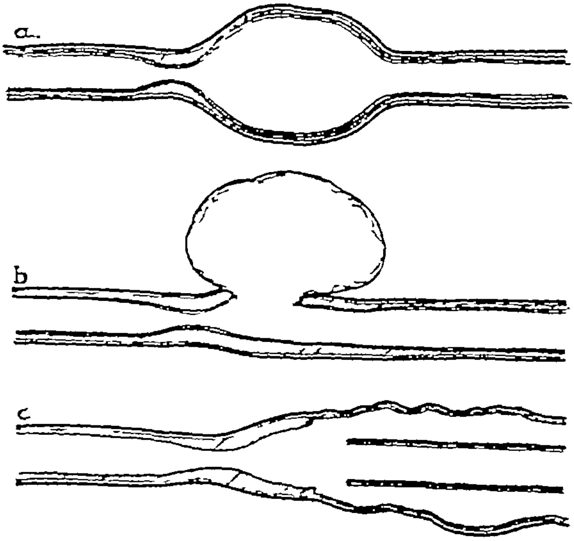

Fig 21 —The play of hydraulic stresses accompanying the flow of blood through a stenosis due to segmental atherosclerosis in an arteriosclerotic aorta may be an important factor in the development of (a) a fusiform aneurysm (b) a sacculated aneurysm or (c) a dissecting aneurysm (see text)

Occasionally, a vessel may show segmentary thickening and rigidity of its wall due to degenerative changes without narrowing of its lumen but with complete destruction of its elasticity and with complete absence of dilatation in systole, whereas immediately distal to this rigid segment the vessel retains its elasticity and distensibility The emergence of a rapidly flowing stream from such a rigid segment into the more elastic and distensible distal segment may initiate a play of hydraulic forces quite comparable to those unleashed distal to a true stenosis, thus setting the stage for the development of an aneurysmal dilatation either fusiform, saccular, or dissecting depending upon local circumstances

Moreover the sudden appearance after many hours of pulsatile flow of a pouchlike dilatation or of a marked irreversible ballooning out of the rubber tubing just beyond a stenosis as observed in several of our experiments may well have its counterpart in the development of aortic aneurysms A weakened area imposed by atherosclerosis or by degenerative processes in the vessel wall just beyond a stenosis may be subjected suddenly to a great increase in the play of these hydraulic forces due to the sudden increase in pulse rate and in general blood pressure accompanying unusual physical activity or great emotional strain The suddenly heightened pressure and the increased velocity of flow through the stenosis increase greatly the hydraulic stresses localized just beyond the stenosis, and a ballooning out of the aorta into a fusiform or a sacculated aneurysm, or even in a tear of the media with the production of a dissecting aneurysm, is the inevitable result

SUMMARY

A mass of fluid ejected through a narrow and limited constriction under high velocity strikes against a more slowly moving mass of fluid distal to the stenosis resulting, first, in the conversion of high kinetic energy into high potential energy or lateral pressure and, second, in the lateral deflection of the rapid stream and even in a complete reversal in its direction of flow, thus resulting in a clash of opposing streams that produces eddies of alternating high and low pressures whose repeated impacts over a prolonged period against an elastic wall are capable of inducing structural fatigue and distention of that wall Accentuating the play of these forces is a third factor the hydraulic principle that a widening stream causes decreasing velocity which in turn produces increasing lateral pressure The resulting interplay of these three factors recurring repetitively with each systole in a pulsating stream, and operating in a limited segment of an elastic vessel, produces eventually and inevitably the phenomenon of poststenotic dilatation It is a highly intriguing thought that this sequence of events may be the initiating and possibly the most important factor in the development of the fusiform dilatations, the saccular aneurysms, or even of the dissecting aneurysms commonly observed in the arteriosclerotic aorta in which segmental atherosclerosis or fibrosis may produce a localized or relative stenosis

The recognition of the potential power of the hydraulic forces liberated beyond a real or relative stenosis may assist in the explanation of the destruction of bone and surrounding structures that occasionally accompanies the development of a thoracic aneurysm They explain also the aneurysmal dilatation of the vein usually seen at the site of an arteriovenous fistula where the arterial stream under high pressure and high velocity is ejected through an abnormal communication into the widened bed of the accompanying vein

The occasional aneurysmal dilatation of the pulmonary artery in the presence of a patent ductus may also be ascribed to the hydraulic forces liberated when the arterial stream of high pressure and high velocity is ejected from the narrow ductus into the wider and less rapidly flowing stream of the pulmonary artery with its lower pressure

It is highly probable, also, that the sudden cerebral hemorrhage attributed to the rupture of a small aneurysmal dilatation has its inception in the precipitate unleashing of hydraulic forces suddenly augmented by the heightened pressure and increased velocity of flow incident to emotional stress or physical exertion

Similarly, sudden death from rupture of a larger thoracic or abdominal aneurysm may follow the sudden increase in blood pressure and pulse rate that accompanies emotional stress or physical exertion and produce an increase in velocity of flow which greatly augments the play of hydraulic forces, with result ing sudden increase in lateral pressure just distal to the junction of the narrow arterial lumen with the greatly widened bed of the aneurysmal dilatation

These and other similar vascular phenomena may find their proper explanation in the application of the hydraulic laws that govern the pulsatile flow of fluid through a system of elastic vessels subjected to real or relative narrowing by congenital abnormalities, by degenerative processes, or by accidental injuries

They give stern warning also of the need to employ, in vascular surgery, methods of end to end anastomosis that permit growth at the site of union as the child grows, thus avoiding future stenosis and methods that prevent or minimize the development of constriction at the site of anastomosis, either by puckering at the time of operation, or by cicatricial contracture as healing progresses

Grateful acknowledgment is hereby accorded to Professor J K. Vennard of the Department of Civil Engineering at Stanford University for his helpful advice and criticism, and to Drs Ernest Schnoor, Eldon Ellis, and Iseu da Costa, fellows in surgery, for their invaluable help in executing the experimental studies presented in this paper

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THE ETIOLOGY OF CHRONIC INTERSTITIAL PNEUMONITIS ASSOCIATED WITH LIPID DEPOSITION

An Experimental Study

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In the last few years a form of chronic interstitial pneumonitis characterized by the presence of intracellular lipid deposition has become recognized as a pathologic entity.[1-8] Such a process may exist alone, behind bronchial obstruction or in association with other inflammatory lesions of the lung. The terms, "cholesterol pneumonia,"[4] "endogenous lipid pneumonia,"[8] and "foam cell pneumonia"[5] have been applied to this lesion to separate it from other forms of pulmonary inflammation. On the basis of the human material that has been studied, the clinical features of the disease and the pathogenesis of the lesion have been outlined in a reasonably satisfactory manner, but no specific etiologic agent has been found, in fact the slowly accumulating information on this subject indicates that the etiology is nonspecific and related to physicochemical conditions within the lung tissue of varied origin. It is surprising that this unusual and sometimes massive deposition of lipid material has not been studied more thoroughly, particularly in relation to the pathogenesis of atherosclerosis and other xanthomatous lesions.

Gross, Brown, and Hatch have reported the development of "endogenous lipid pneumonia" in rats after prolonged breathing of an atmosphere containing particulate antimony trioxide and on instillation of similar material intratracheally.[6] They suggested that accumulation of cholesterol resulted from nutritive derangement of macrophages detached from alveolar walls. Fienberg has described observations on human autopsy and surgical specimens which indicate to him that allergic phenomena affecting the bronchioles resulted in obstruction of the terminal portions of the bronchial system and that the appear

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ance of cholesterol was secondary to obstruction. Chiari[5] considered chronic lymphatic obstruction to be etiologically important, but both he and others[4] recognized certain objections to this explanation.

Our investigations have centered about attempts to reproduce this lesion in experimental animals. Bronchial obstruction by ligature or placement of foreign bodies within the bronchial lumen did not cause intrapulmonary lipid deposition in rabbits or dogs. The instillation of suspensions and emulsions of cholesterol

Fig 1

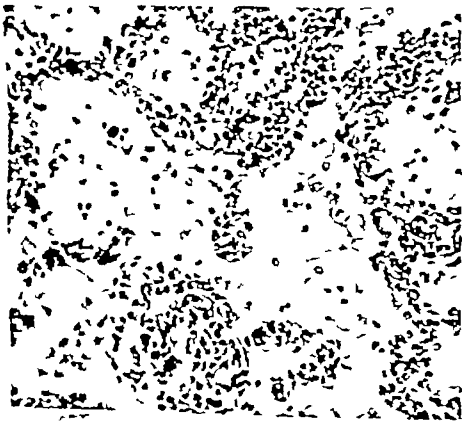
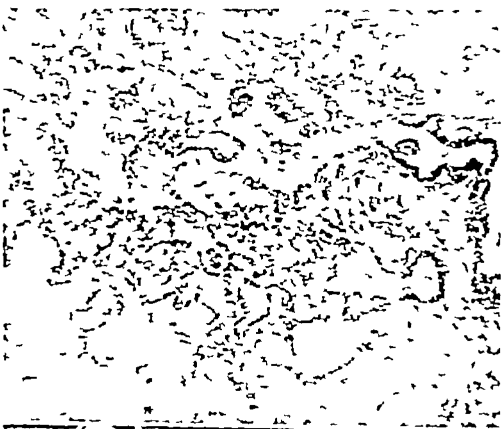


Fig 2



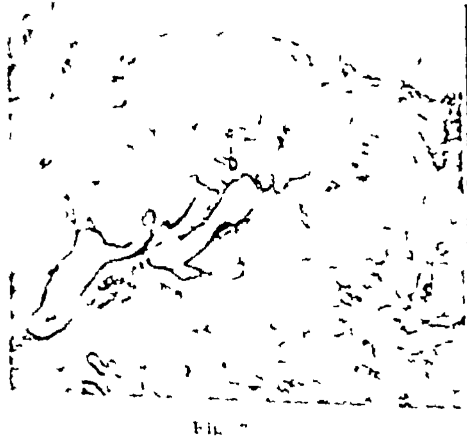


Fig 3

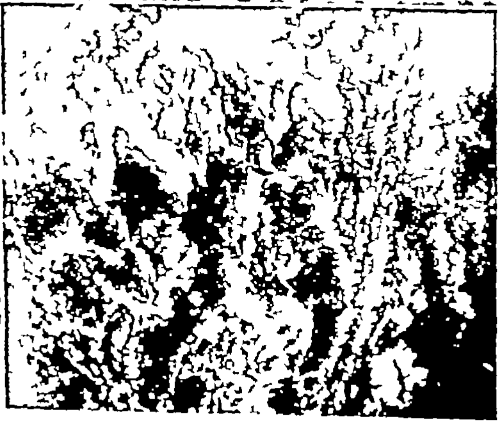


Fig 4

Fig. 1.—The early lesion in human cholesterol pneumonitis showing lipid filled macrophages in the interstitial tissue and air spaces (Hematoxylin and eosin)

Fig. 2.—A primary lobule in human cholesterol pneumonitis The interstitial tissue is filled with lipid containing macrophages and there is beginning fibrosis The alveoli are [illegible] leaving only alveolar ducts containing macrophages (Hematoxylin and eosin)

Fig. 3.—End stage of human cholesterol pneumonitis A terminal bronchiole and branching alveolar ducts are embedded in dense collagen (Hematoxylin and eosin)

Fig. 4.—Doubly refractile material outlining the alveolar wall (digitonin precipitation)

into the lungs of rabbits caused inflammation and foreign body reaction which did not resemble the human lesion. X radiation (1,600 r) of rabbits' lungs did not result in a pathologic picture that was similar to the human lesions.

Recently it has been possible to produce a form of chronic pneumonia in rabbits in which large quantities of fat and cholesterol are deposited within activated macrophages in the lung parenchyma.[9] These experiments were carried out in two groups of rabbits. One group of animals was made lipemic by feeding cholesterol and oil. A second group of animals was maintained on stock diet. Pulmonary infections were produced in these two groups of animals by the intratracheal instillation of saline suspensions of *Pasteurella pseudotuberculosis* and a strain of *Klebsiella pneumoniae* isolated from a fatal case of pneumonia. The animals were sacrificed or died at intervals from four hours to forty-seven days. The lesions that resulted from these infections were observed grossly and studied histologically, after section and staining with hematoxylin and eosin and Sudan IV. The cholesterol-fed animals had serum cholesterol levels ranging between 1,500 and 3,400 mg. per 100 ml. of serum at the time the infections were produced.

Further observations upon the deposition of lipid in inflammatory tissues were made by ligating the major blood supply to the tibialis anticus muscles in normocholesterolemic and in hypercholesterolemic animals.

RESULTS

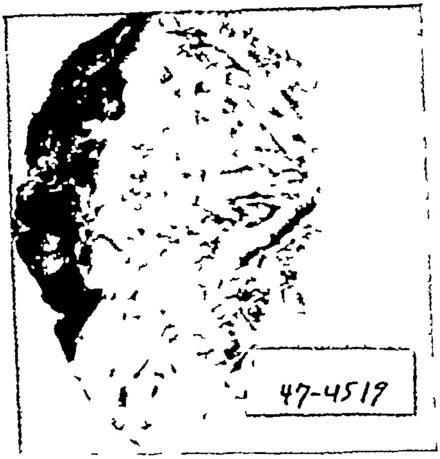
I. Gross Observations.—In nonlipemic animals *K. pneumoniae* or *Past. pseudotuberculosis* usually caused only small focal areas of pneumonitis some of which were identifiable only on microscopic examination. However, two animals infected with *Past. pseudotuberculosis* died within forty-eight hours of acute hemorrhagic edema without cellular exudation. The minimal lesions in normocholesterolemic (stock-fed) animals contrasted sharply with the large areas of consolidation that developed in the lungs of lipemic, hypercholesterolemic (cholesterol-fed) animals. Grossly the consolidated areas were whitish-yellow and varied from lobular distribution to massive solidification of almost the entire lung. The involved areas were airless and there was no expressable exudate. The intervening parenchyma appeared normal.

II. Microscopic Observations.—

A. Hypercholesterolemic animals. 1. Friedlander's bacilli injected intratracheally caused an initial diffuse acute pneumonitis followed by an interstitial reaction characterized primarily by large numbers of macrophages in the alveolar walls and alveolar epithelialization with apparent desquamation of the septal cells into the air spaces. Large quantities of lipid were found in all these cells regardless of their position within the lung parenchyma (Fig. 8). Cholesterol and fat were present in activated septal cells still attached to the alveolar walls, in macrophages within alveolar walls, and in free lying macrophages in the alveolar spaces.

2. In the lungs of animals with hypercholesterolemia, *Past. pseudotuberculosis* produced an acute pneumonitis with large areas of necrosis. The surrounding zone of reaction contained many macrophages filled with lipid granules. In this zone the swollen septal cells contained lipid granules. Sudanophilic material was also present in the endothelial cells of the capillaries and pleural mesothelial cells.

B. Normocholesterolemic animals. Friedlander's bacilli introduced into the lungs of rabbits on stock diet produced a focal acute pneumonitis in the first ig 5



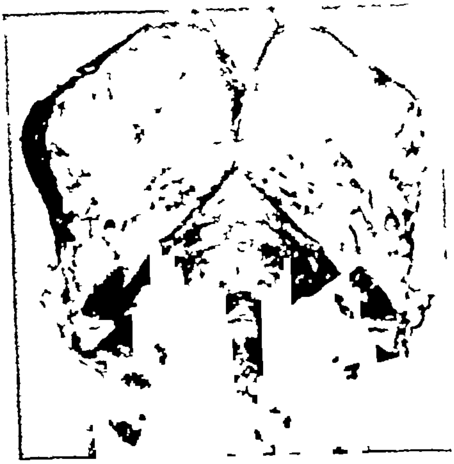
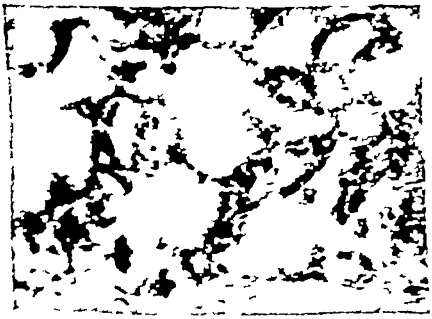


Fig 6

Fig 7



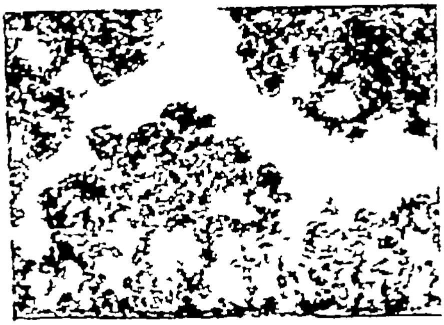
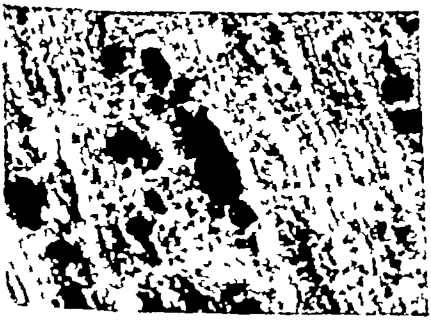


Fig 8

Fig 9



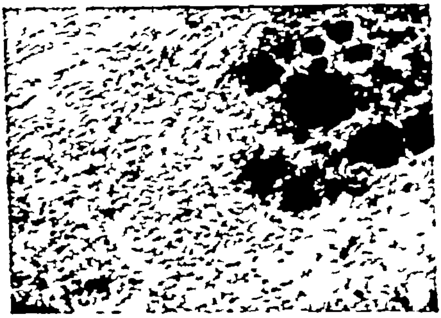


Fig 1

Fig 5.—Cut section of right middle lobectomy specimen showing complete consolidation [illegible] pneumonitis. The bronchi are freely patent.

Fig 6.—[illegible] pneumonitis distal to a stenosing bronchial carcinoma (arrow).

Fig 7.—Fat stain in human cholesterol pneumonitis showing lipid-filled macrophages in [illegible]. (Sudan IV and hematoxylin.)

Fig 8.—Fat stain of an area of pneumonitis in a hyperlipemic rabbit infection with [illegible] lipid-filled macrophages [illegible] in the interstitial tissue. (Sudan IV and hematoxylin.)

Fig 9.—[illegible] lipid accumulation in the reacting cells of ischemic muscle of a lipemic rabbit. (Sudan IV and hematoxylin.)

Fig 10.—Minimal lipid accumulation in the reacting cells of ischemic muscle of a stock [illegible] with Fig. 9. (Sudan IV and hematoxylin.)

few hours and subsequently an interstitial pneumonitis without tissue destruction. The exudate consisted of lymphocytes, neutrophils and eosinophils and in particular a large accumulation of macrophages in the swollen alveolar walls. There was focal migration of the macrophages into the air spaces. Fat stains demonstrated only a few lipid granules in a small number of macrophages.

C. Muscle ischemia. Ischemia in the muscles of rabbits resulted in acute necrosis of the fibers with a neutrophilic infiltration and subsequent proliferation of endomysial fibroblasts. In hypercholesterolemic animals there was a pronounced accumulation of lipid in the proliferating endomysial cells, whereas in stock fed animals very few lipid granules had accumulated (Figs. 9 and 10).

DISCUSSION

The experimental results described herein may help to clarify some aspects of the pathogenesis and etiology of cholesterol pneumonitis in man. (1) The influence of elevated blood lipid levels upon reactions to infection has been explored. (2) The origin of the lipid material and one mechanism by which it enters the alveolar spaces seems reasonably certain. (3) There is an indication of the pathway by which fat and cholesterol may appear within macrophages. (4) Comparison of the pulmonary reaction produced by infection in the presence of lipemia with the reaction in ischemic muscle in the presence of lipemia allows certain inferences concerning the etiology of human chronic pneumonia associated with large lipid deposits.

It is clear that under the conditions of these experiments elevated blood lipid influences the character and extent of inflammatory response in lung. In the animals infected with *Past. pseudotuberculosis*, for example, five of six lipemic animals died, whereas only two of eight nonlipemic animals died. Both of the animals in the latter group died within two days of hemorrhagic pulmonary edema. The survivors of this acute phase of the infection remained healthy and when sacrificed had normal lungs or minimal lesions. This contrasts dramatically with the extensive areas of gross consolidation that developed in the lipemic animals. The reason for this difference is not clear, but large quantities of fat and cholesterol may hamper healing and project the inflammatory reaction into a chronic phase. Cholesterol deposited in tissues is removed with difficulty[10] and its presence could account for the persistence and extension of inflammation. However, the influence of lipid deposition upon bacterial virulence and defense mechanisms remains to be explored. For example, it is possible that the function of macrophages may be impaired by a large quantity of lipid in the cytoplasm.

The lipid that accumulates within the macrophages appears to originate from the blood stream. This is indicated by the fact that in lipemic animals the edema fluid that floods the alveoli in the early stages of Friedlander's pneumonia (animals sacrificed four hours after infection) is filled with minute sudanophilic droplets. These droplets are larger than the chylomicrons of the blood and probably have coalesced to some degree. Süllman and Verzar[11] have shown that serum lipids permeate collodion membranes to about the same extent as proteins, and lipids have been demonstrated to pass from blood into lymph.[12]

It is logical that the influx of fat and cholesterol occurs from the blood stream through a damaged capillary bed in the same manner as other colloidal substances have been shown to enter inflammatory sites.[14, 16]

In these experiments activated septal cells, and macrophages lying free in the alveolar space and in the alveolar walls were noted to be heavily laden with lipid material. Furthermore, in some areas of infection capillary endothelial cells were filled with fat droplets. This indicates that factors other than the mere presence of lipid within the alveoli are also of importance. Consequently the suggestion by Gross, Brown, and Hatch that lipids accumulate in intra-alveolar macrophages because of nutritive derangement seems unlikely. However, lipids released into the tissues by disintegration of the phagocytes may result in the continuation of the inflammatory response.

In hypercholesterolemic animals the accumulation of fat and cholesterol in phagocytes mobilized to clear away devitalized muscle is pertinent to experimental lung infection in the presence of lipemia. Bacterial infection was not present in the muscle indicating that it is not a prerequisite to rapid intracellular lipid accumulation. The environment in ischemic muscle and infected lung may be similar, namely, cellular breakdown products, local acidosis, activated macrophages, damaged capillaries, and lipemia. It is concluded that the physicochemical environment is of prime importance, and that the human lesion is not specifically related to any particular etiologic agent.

There is no evidence that hyperlipemia is necessary for the development of cholesterol pneumonitis in human beings. The few patients on whom blood lipid levels were measured have not shown an elevation of total fatty acids, phospholipid, cholesterol, or cholesterol esters.[1] The fact that qualitatively similar lesions have been produced in animals on stock diet gives some assurance that the differences between stock-fed animals and cholesterol-fed animals are only quantitative.

In summary, intrapulmonary deposits of large quantities of fat and cholesterol have been observed in human beings, rabbits, and rats. Such lesions have been produced in rabbits as a result of two different bacterial infections and by the inhalation of particulate antimony trioxide in rats.[8] Muscle degeneration in the presence of lipemia resulted in the accumulation of fat and cholesterol in macrophages mobilized in the usual process of removing devitalized tissue. In the aorta several forms of trauma[18] and methionine deficiency[19] have led to atheromata in experimental animals. Pyridoxine deficiency can lead to arteriolar lesions with lipid deposition.[20] Fat and cholesterol accumulation in sites of chronic inflammation is a common occurrence. The common denominator would seem to be tissue injury resulting in a change of the local physicochemical conditions.

SOME GENERAL CONSIDERATIONS RELATIVE TO THE ABNORMAL DEPOSITION OF LIPIDS IN TISSUES

The water-insoluble lipids of the blood and tissues exist for the most part as stable protein lipid complexes in colloidal solution or suspension. Like other colloid systems the stability of lipid emulsions in the blood and tissues is dependent in part upon the electrostatic repulsion between individual molecules, micelles, and particles of like charge (a negative charge in the case of lipids). Many alterations, among them the hydrogen-ion concentration, can result in agglutination and coalescence of individual particles and 'breaking' of the colloidal system. The properties of colloidal lipids are contributed to in part by the associated proteins. For example, the lipoprotein in which most of the serum cholesterol is found has an isoelectric point about 5.4.[21] Among the physical and chemical changes that occur in inflammatory tissue that might influence the behavior of lipids, the hydrogen-ion concentration in exudates and reacting cells seems of fundamental importance. Perhaps of equal importance is the behavior of proteins or other substances and their influence upon negatively charged anionic molecules, micelles and particles.

Hydrogen-Ion Concentration in Injured Tissue.—It is known that tissue injury and infection result in local acidity. The increased hydrogen-ion concentration is the result of lactic acid accumulation during anaerobic or partially anaerobic glycolysis.[22] The pH values of most exudates fall in the range of 6 to 7.[23] In injured tissues there is little data based on direct measurement and hydrogen ion concentration has been measured under few in vivo conditions. Indeed the major effort of most physiologists working in this field has been to avoid the effects of injury. The most important contributions in this regard have been made by Needham and Needham,[24] Rous,[25] Gilding[26] and Chambers and associates.[27, 28] Chambers gives a pH of 5.3 in injury and cytolysis. Cytoplasmic inclusions in amoebae were below pH 5.0 and apparently more acid than the surrounding protoplasm. The cytoplasmic inclusions were found to be responsive to changes in environmental pH, whereas the remainder of the cytoplasm and nucleus were not. These figures are at or near the isoelectric point of many tissue proteins and on the acid side of some. Rous found a pH of 3 or below in the cytoplasmic granules of phagocytes using litmus as an intracellular indicator.

The importance of hydrogen ion concentration in regard to lipid deposition arises from the amphoteric nature of proteins, the effect of lowering the pH upon the actual and net charge exhibited by proteins, and the effect of these alterations upon the negatively charged colloidal lipids. Furthermore, even in the absence of proteins, changes in pH affect the stability of colloidal lipid, for each emulsion or colloidal solution is characterized by an isoelectric area. Shifts of pH toward the isoelectric point of a colloidal system detract from the stability of that system. Negatively charged lipid particles or molecules may be coalesced, agglutinated, or precipitated by pH changes that approach the isoelectric point. Similarly, nullification of charge by other material may cause 'breaking' of colloidal systems. It is believed that such phenomena are responsible in part for lipid accumulation in abnormal loci such as infected lung or ischemic muscle. A similar explanation may account in part for the localization of fat and cholesterol in the cytoplasm of macrophages.

The Reaction Between Basic Proteins and Lipids.—Some important features of the reaction between phospholipids and proteins are known. Also the extent and nature of the binding of other anions by proteins have been investigated.[32-36] This information has not been applied to the understanding of abnormal lipid deposition in tissues. One of the constant changes accompanying tissue injury or infection is an increased hydrogen-ion concentration which may involve individual cells, small groups of cells, or large masses of tissue. One of the effects of such an alteration may be that the local pH approaches or falls below the isoelectric point of some of the tissue proteins of the injured area. In general as the pH falls the proteins in that environment behave more like bases until at the isoelectric point the negative and positive parts of the molecules theoretically balance one another. Below the isoelectric point the positively charged loci of the molecule predominate and the molecule as a whole behaves as a positively charged base. Such basic molecules can react directly or form firm complexes with a variety of anions. In a broad sense the negatively charged lipids can be considered to behave as anions. Even such relatively large particles as chylomicrons enter into protein-lipid complexes that disrupt the colloidal system holding them in suspension. Complexes formed between basic proteins and lipids can generally be dissociated when the pH reverts to the alkaline side. This fact may have some bearing on the disposition of precipitated lipid in a healing lesion. At pH 4 to 5 protein-lipid complexes have been formed using normal blood serum, aqueous extracts of muscle, purified albumin, tryptic digests of serum and muscle. Phospholipid stabilized artificial triglyceride emulsions, the blood lipids of rabbits and human beings, and emulsions of pure phospholipids have been shown regularly to enter into combination with the variety of proteins mentioned above.[37]

Some proteins with high isoelectric points form stable complexes at all pH levels within the physiologic range. Protamine is a notable example of such a protein having an isoelectric point near 12.[38] Histones behave similarly. Small peptides of this sort appear from the disintegration of tissues of many types. The cleavage of nucleoprotein could result in the appearance of considerable quantities of material having qualities similar to protamine and histone.

It appears reasonable that the deposition of neutral fat, phospholipid, and cholesterol in areas of disintegrating tissue or areas of inflammation should be explained in part at least on the basis of pH changes and the reactions between amphoteric proteins of the involved tissues. Similar phenomena explain the localization of colloidal dyes and metals in areas of inflammation.[1] Undoubtedly degeneration of some tissues results in more striking effects than others and this may be explainable on the basis of the products resulting from injury to and disintegration of certain tissues. The elastin of arteries, the collagen of tendons, the ground substance itself are protein, and the slow liberation of breakdown products following injury of a variety of sorts may be one of the principal causes of the accumulation of lipid material in these tissues.

SUMMARY

K. pneumoniae and *Past. pseudotuberculosis* in the presence of high blood lipid levels produced a pneumonitis in rabbits characterized by deposition of large quantities of cholesterol and fat in the inflammatory areas. The pathologic lesions closely resembled cholesterol endogenous lipid or foam cell pneumonia previously described in human beings and were similar to several other types of xanthomatous lesions. In the presence of normal blood-lipid levels fat and cholesterol also appeared in small amounts in chronically inflamed areas. Similar phenomena occurred in ischemic muscle suggesting that the process was dependent upon local physicochemical conditions. The suggestion is made that local acidosis developing in an injured or infected tissue has an adverse effect upon the colloidal lipids. The effect of lowered pH is largely on the charge exhibited by colloidal lipids and proteins. The pathologic significance of the reaction between basic proteins, phospholipids and negatively charged (anionic) lipids is discussed.

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DISCUSSION

DR EDGAR W DAVIS, Washington, D C—I have a feeling that this subject is of much greater importance than most of us recognize at the present In the first place, there have been quite a few cases of lipid pneumonia reported as industrial hazards In the second place, there is a segmental type of lipid pneumonia which presents a distinct diagnostic problem in differentiating it from bronchiogenic carcinoma or other forms of neoplastic disease During the last twelve years we have operated upon six patients with "localized" or "segmental" lipid pneumonia which we believed preoperatively to be carcinoma A report of these cases is being published in the JOURNAL OF THORACIC SURGERY Of our six patients operated upon, only three had had bronchograms and in two of those the contrast media did not enter the diseased segments Three of the patients gave a clinical history of the ingestion, over a period of many years, of large quantities of mineral oil for constipation One patient had a long history of the use of oil nose drops and one patient was a high altitude aviator who used petroleum jelly around his nose and mouth to make his mask fit better One other patient gave no history of the use of oil and had not had a bronchogram Our pathologists felt that all of these presented the same microscopic appearance and the diagnosis of lipid pneumonia was made

I should like to ask Dr Waddell how a diagnosis of lipid pneumonia can be made preoperatively Obviously, if the disease is a localized or a limited one, surgery is certainly in order When the disease is diffuse and/or mottled in appearance, we should have some way of making the diagnosis In a few patients not operated upon, but whose x rays and clinical history led us to make a diagnosis of lipid pneumonia, we have done bronchoscopies with bronchial washings repeated bronchial washings by means of a bronchial catheter, sputum examinations and even aspiration biopsies of the diseased lung, but these specimens have failed to reveal the lipid elements The one patient in our reported series who did not have a history of the use of oil and in whom a bronchogram had not been done makes me wonder whether or not it is possible for this to be the product of something that is not necessarily oil Could this be the result of metabolism of cholesterol, etc ?

I enjoyed Dr Waddell s presentation immensely

DR LEO ELOESSER, San Francisco, Calif —I agree that this is an interesting and important subject I wonder whether the paraffin aspiration pneumonias to which I think Dr Davis refers are the same as those Dr Waddell was discussing I wonder whether Dr Waddell could tell us whether the lipemia is the cause or the effect of the disease There is a disease among sheep known as pseudotuberculosis, an epidemic disease which strikingly resembles *in the gross at least the pictures* which Dr Waddell showed us today Some of the members *from the no longer wild but still woolly* West probably know more about this disease than I do If it occurs in sheep spontaneously perhaps the sheep would be a more appropriate animal to work with than rabbits

DR HAROLD A LIPP, Pittsburgh Pa —I rise to discuss this paper briefly in the light of reviewing some ancient history with which I am intimately acquainted About 1919, under the direction of Dr Oskar Klotz a Canadian gentleman of distinction, at the University of Pittsburgh I studied the variations in cholesterol in the blood serum in pneumonias He had been interested in the deposition of cholesterol in the walls of blood vessels This work was reported in the JOURNAL OF BIOLOGICAL CHEMISTRY Volume 44, 1920

The cholesterol content of the blood serum in pneumonias exhibits the following variation

a A primary hypocholesteremia, the degree of which is dependent upon the degree of lung involvement and the intensity of the infection

b A secondary hypercholesteremia in the period of convalescence during and continuing for a varying period of time after the resolution of the pneumonic exudate

c A return to the normal cholesterol content of the serum

The variation in the cholesterol in the blood serum in pneumonias is dependent upon the activity of the leukocytes [illegible] being transported by them to the area of acute inflammation [illegible] an antitoxic substance neutralizing the bacterial toxins and those arising from the fragmentation of tissues in the process of the inflammatory reaction It may also serve as an adjuvant in the development of antigens which initiate the process of resolution of the pneumonic exudate The utilization of cholesterol in acute toxic infections is directly proportional to the severity of the disease The development of empyema definitely alters the variation of cholesterol in the serum of pneumonia

[illegible] that the cholesterol content of the cellular portion of empyema [illegible] high as that of the fluid portion This characteristically refrac[illegible] especially in the macrophages of the exudate Since these [illegible] of the blood serum we presumed that the method of transport of [illegible] cholesterol from blood to tissues was thus suggested In the presence [illegible] pulmonary parenchyma, the transport of cholesterol [illegible] or prevented

DR WILLIAM E WADDELL [illegible] —In response to Dr Davis inquiry [illegible] sharp [illegible] this form of pneumonia [illegible] with lipid deposition [illegible] lipid pneumonia The microscopic picture is easily [illegible] today the lipid is [illegible] of macrophages and the droplets are extracellular minute In either mineral oil, cod liver oil, or other forms of aspiration lipid pneumonia or paraffinomas, the droplets vary greatly in size, and even at a glance the pathologist can distinguish between the two diseases

The question was asked as to whether lipemia was the cause or the result of the disease It certainly was not the result of the disease The control series of animals underwent the same type of infection as the experimental animals and maintained normal blood lipids The point we would like to make is that the lipemia influences the disease, it influences the normal course of two types of infection in rabbits simply by its presence

I think the suggestion about study of the disease in sheep is pertinent to this problem and perhaps to the deposition of lipids in other diseases, principally those of the blood vessels because it would offer an experimental setup that would perhaps be more to the point than a hyperlipemic rabbit I think Dr Kipp's work back in 1920 was very instructive and it pointed the way to a good deal more work that followed along the same lines In fact the measurement of lipid content of sputum was proposed at one time as a prognostic sign in following the course of pulmonary tuberculosis It was ultimately given up because it correlated principally with the destruction of tissue, although it did have its advocates over a number of years

I should like to thank each of the discussants

ABSENCE OR HYPOPLASIA OF A PULMONARY ARTERY WITH ANOMALOUS SYSTEMIC ARTERIES TO THE LUNG

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THE interrelationship of the pulmonary and bronchial circulation in the lungs is of clinical and scientific importance. Pathologic and experimental data demonstrate the tendency for the bronchial component of this dual vascular system to enlarge when the pulmonary artery becomes smaller or is occluded. Similarly, congenital absence or hypoplasia of the pulmonary artery to a lung is often associated with compensatory growth of the bronchial or systemic vasculature of that lung. Such alterations in the blood vessels of the lung are frequently seen in association with those congenital cardiac lesions which have an absence or hypoplasia of the main pulmonary artery, and the enlargement of the bronchial blood flow plays an important role in the survival of some of these cardiac patients. Congenital anomalies of the pulmonary and systemic arteries to a lung may also occur unassociated with primary heart disease. Numerous instances of anomalous arteries from the systemic circulation being found in association with bronchogenic cysts, congenital bronchiectasis, and sequestration of a portion of the lung have been reported.[1-4] Less common is the finding of a large systemic artery delivering arterialized blood to a lung which shows no evidence of gross anomalous development of the pulmonary tissue.[5, 6] Congenital absence of the right or left pulmonary artery may occur without abnormality of the bronchial tree or lobar development.[7-16] In other instances a unilobar or hypoplastic lung without cystic or bronchiectatic lesions may be supplied by a small pulmonary artery and anomalous systemic arteries. Such congenital anomalies of the pulmonary and systemic vessels to one lung may result in certain alterations in the blood flow of that lung which sometimes produce symptoms. Moreover, the vascular arrangements that occur in such lungs are of considerable scientific interest in an investigation of the dual pulmonary vascular system. The clinical and radiologic features of (1) absence of the pulmonary artery to one lung and (2) hypoplasia of one lung with anomalous systemic arteries is the subject of this paper.

A consideration of the embryology of the pulmonary artery and its relation to other vascular channels in the lung buds aids the understanding of the development of anomalous systemic arteries to the lung. The pulmonary vasculature is derived from both a ventral and a dorsal anlage which are joined together by the postbranchial pulmonary plexus. The dorsal anlage arises

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[illegible]

[illegible]

[illegible]

[illegible]

from the aortic branches (Fig 1) Normally these aortic connections largely disappear as the ventral segment of the plexus becomes a better-defined channel which ordinarily develops into the main pulmonary artery But if the ventral connection to the pulmonary plexus should fail to develop normally, the dorsal aortic branches may persist Then the lung in postnatal life may continue to receive branches from the aorta Thus in the embryologic development of the

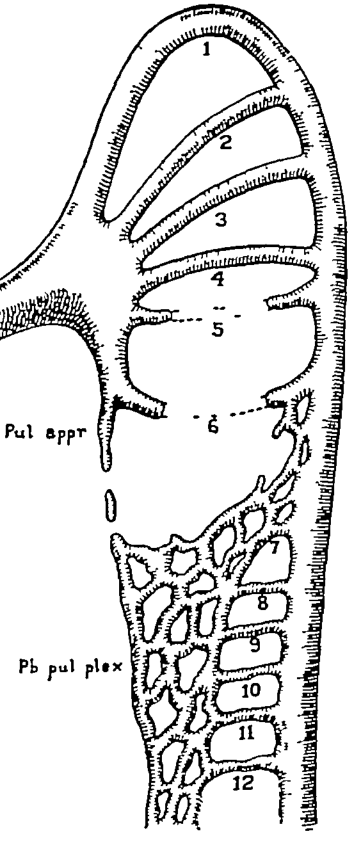


Fig 1—Schematic presentation of the development of the aortic arches pulmonary plexus and pulmonary artery *Pul appr* Pulmonary artery bud Pb pul plex postbranchial pulmonary plexus Arches 7 to 12 represent communications between aorta and the pulmonary plexus (Reproduced from Huntington G S The Morphology of the Pulmonary Artery in the Mammalia, Anat Rec. 17 165 1919)

pulmonary vasculature there is a similar tendency for the systemic or aortic components to compensate for a deficiency in the pulmonary artery channels as there is in postnatal pathologic processes Likewise the mechanism of development of the bronchial collateral blood flow to the lungs in hypoplasia or atresia of the pulmonary artery of congenital heart disease is understandable

It would seem logical to assume that the earlier the embryologic aberration occurs in one component of the dual vascular system of the lung, the more extensive the changes in the other component might be It would also appear likely that the network of vessels connecting the two vascular systems in the lung in certain congenital anomalies of the heart and lungs may be different than those produced by experimental or surgical procedures which alter the blood flow in any part of the dual system in postnatal life. Since the intrinsic intrapulmonary vascular pattern may differ in many ways depending on the exact type of vascular anomaly present, full information must await injection studies of the various types of cases.

ABSENCE OF THE PULMONARY ARTERY TO ONE LUNG

Greater use of angiocardiography has demonstrated that congenital absence of one pulmonary artery is not the extreme rarity which the literature would suggest.[1] Since some patients with this anomaly are free of significant symptoms, the condition will be definitely diagnosed only if some suggestive features of the routine chest roentgenogram are appreciated and further investigations undertaken. At present the data are too meager to justify final conclusions but presentation of current information may aid in further evaluation. This discussion is not concerned with atresia of the main pulmonary artery in tetralogy of Fallot or other major congenital cardiac lesions.[2]

When the blood flow through one pulmonary artery is reduced or absent, either as a result of disease, surgical intervention or congenital anomaly, the respiratory function of such a lung is largely lost. The ventilation may diminish to a varying degree. There tends to be an increase in the bronchial circulation with an increase in the functional communication between the pulmonary and bronchial vascular systems. Under conditions of marked anoxia or great carbon dioxide retention some respiratory function may be elicited in a lung which has no pulmonary artery but is supplied entirely by systemic vessels. The situation with congenital absence of one pulmonary artery may not be the same as when the main branch to one lung is occluded by disease or surgical intervention. In the case of the occluded pulmonary artery the extensive vascular channels distal to the site of obstruction may remain patent to a greater or less degree and receive blood via communications with the bronchial arterial system. Information concerning the detailed vascular arrangement within the lung in congenital absence of the pulmonary artery is lacking. Moreover the pattern will probably vary from case to case since the magnitude of the blood supply from the systemic arterial system may vary widely. Such differences in the arterial blood supply in cases of absence of the pulmonary artery may result in marked variations in the clinical and radiologic findings [illegible] that [illegible] indications [illegible]

Certain radiologic findings in congenital absence of a pulmonary artery [illegible] the diagnosis on the conventional chest roentgenogram[12] [illegible] very [illegible] the same lung. The chief findings are [illegible] abnormal lung although the entire lung [illegible] 2 [illegible] normal hilar vascular shadows of that [illegible]. The [illegible] abnormal lung results in mediastinal dis[illegible] lung and overdistention of the contralateral lung with varying degrees of mediastinal herniation (Fig 5) The diaphragm on the abnormal side is sometimes elevated The degree of reduction in volume of a lung without a pulmonary artery varies considerably In some cases the lung appears only slightly smaller than normal, whereas in other instances the reduction is considerable This variation in lung size will naturally influence the degree of mediastinal displacement and herniation, and position of the ipsolateral leaf of the diaphragm In some cases fluoroscopy will demonstrate mediastinal shift toward the abnormal side on deep inspiration but this finding may be absent if the lung ventilates well The volume of a lung without a pulmonary artery may be altered by superimposed infection to which such lungs seem to be susceptible (Fig 2) Also during life it may be difficult to ascertain definitely whether the lung has a normal number of bronchopulmonary segments unless a complete bronchographic visualization has been obtained

Another aid in suspecting the diagnosis of absence of a pulmonary artery to one lung is to note the relative size of the hilar vascular shadows on the two sides There will be a decrease or absence on one side with enlargement on the opposite side The roentgen demonstration of diminished hilar vascular markings on conventional films is easier on the right than on the left side When the pulmonary artery branch is absent on the left side, the displaced heart tends to overlie the hilar area in the posteroanterior projection

The effect of congenital absence of a pulmonary artery branch to one lung can be considerably altered by the size and magnitude of the systemic vascular supply to that lung Angiocardiography can give some important information about this blood flow if many films are taken in rapid succession In cases without congenital cardiac disease the bronchial arteries, although larger than normal, are usually relatively small If the lung without a pulmonary artery receives a very large systemic artery as in Case 3, very different clinical and radiographic findings are present (Fig 7) The angiocardiogram usually demonstrates a fine network of bronchial vessels supplying the lung without a pulmonary artery These vessels become opacified after the aorta has been visualized and at a time when the opaque material may have already largely cleared from the pulmonary veins of the contralateral lung (Fig 6) This vasculature may not correspond closely in its relative distribution to the normal bronchial vascular system In Case 2 the prominence of these bronchial vessels at the periphery of the lung is notable If one bears in mind that the pleura in man derives its blood supply from the bronchial system, the large size of the vessels in that location is understandable In this patient the densities cast by these collateral vessels were sufficiently prominent on the conventional film to have been incorrectly interpreted as tuberculous infiltrations

When a lung receives no branch from the main pulmonary artery, the entire blood supply naturally comes from systemic arteries which carry arterialized blood Although such a lung ventilates there is no oxygen uptake from the gas in the alveoli unless the partial pressure of oxygen in the alveoli is greater than that in the arterial blood, which would only occur under abnormal circumstances The amplitude of pulmonary ventilation noted in the lung without a pulmonary artery has been less than that of the contralateral lung with normal pulmonary circulation. Therefore fluoroscopic examination may show deviation of the mediastinum toward the abnormal side during inspiration. This unequal ventilation may lead to an erroneous diagnosis of partial atelectasis.

In consideration of the total pulmonary function in the absence of a pulmonary artery to one lung, it must be borne in mind that a number of factors may play a role. The age of the patient, the side of the abnormality, the degree of reduction in the volume of the abnormal lung in various phases of respiration, and the extent of the bronchial and other systemic blood supply may all influence the result.

Studies of the pulmonary function in a case of congenital absence of the pulmonary artery branch to the right lung have been made by Madoff, Gaensler and Strieder. Their 14-year-old female patient showed a moderate reduction in pulmonary volumes but no evidence of emphysema. The only distinctly abnormal finding was a total ventilation which was almost twice normal because both lungs ventilated although only one absorbed oxygen. Hence there was a marked increase in the ventilation equivalent. The arterial oxygen saturation was normal.

Sternberg, Dotter and Lukas[11] have made studies of the pulmonary function in two adults with congenital absence of a main branch of the pulmonary artery. The lung volumes, maximum breathing capacity, ventilation and blood gases were normal in a 24-year-old man with absent left pulmonary artery. In a 48-year-old woman with absent right pulmonary artery there were increased residual and total lung volumes and slight diminution of maximum breathing capacity, but intrapulmonary mixing and alveolar distribution of air were normal. Cardiac catheterization studies in the young man showed normal pulmonary artery pressure at rest with mild pulmonary arterial hypertension during exercise that doubled the cardiac output.

Because of the small number of cases of absence of the pulmonary artery which have thus far been observed, only tentative recommendations concerning therapy can be made at this time. If superimposed pulmonary infection is not present and if the anomalous systemic circulation is not of such magnitude as to cause significant cardiocirculatory derangement, no surgical intervention seems indicated. In some cases the symptoms of chronic infection in the pulmonary tissue with abnormal circulation may indicate resection. In the rare instance in which the systemic blood flow to the anomalous lung is unusually large and results in pulmonary congestion with or without cardiac enlargement, surgical procedures aimed at reducing, rerouting or removing these anomalous channels must be considered. The autopsy findings in Case 3 indicated that an essentially normal distribution of the blood flow to both lungs might have resulted from a surgical transfer of the proximal end of the anomalous artery from the aorta to the side of the main pulmonary artery.

It should be noted that in our cases with symptoms of recurrent pulmonary infections there seemed to be a discrepancy between the severity and chronicity of the pulmonary process as judged from the clinical history when compared with the gross and microscopic findings of the abnormal lung. The history seemed typical of bronchiectasis, yet repeated bronchograms showed no ectasia. Grossly and microscopically the evidence of inflammatory infiltration was meager in view of the symptomatology. Microscopically there was slight dilatation of the smaller bronchi, but the striking feature was the rather uniform thickening of the interalveolar tissues. One wonders, therefore, whether the deranged *circulation played a significant role* in the pulmonary symptomatology. Reliable statements concerning the walls of the blood vessels within the lung must await more extensive studies.[11]

CASE 1.—A 9 year old boy had a history of recurrent pneumonia, productive cough, and occasional hemoptysis. His respiratory symptoms dated to infancy when coughing and wheezing were noted. Bronchiectasis had been suspected for many years, but several bronchograms had been normal. Roentgenograms taken in earlier years had shown asymmetry of the thorax with narrowing of the interspaces on the right side and deviation of the mediastinum toward the right which increased with the passage of time (Fig. 2, *A* and *B*). In 1953 an anomalous blood supply to the right lung was first suspected and angiocardiograms were done. These revealed an absence of the right pulmonary artery (Fig. 3). Opacified blood was first seen to enter the right lung at the time that the aorta was visualized but no large branches to the right lung were noted (Fig. 4). Because of the history of repeated respiratory infections with productive cough and occasional hemoptysis, pneumonectomy was recommended and performed on Sept. 14, 1953. At operation there were no visceroparietal adhesions present in spite of the history suggesting repeated and long-standing pulmonary infection. The visceral pleura of the lung had a very unusual appearance in that it was a thickened layer, light gray in color, and showed numerous tiny bronchial vessels coursing over its surface. There were three lobes to the right lung with a rather well defined interlobar fissure in the usual location. There was considerable evidence of bronchial collateral circulation in the region of the pulmonary ligament and over the lower portion of the hilum, but this was considerably less marked over the upper lobe where a 4 mm. systemic artery entered the lung at the upper border of the right upper lobe bronchus. This artery came from a systemic vessel high in the chest and descended along the trachea. This vessel had a thicker wall than a pulmonary artery of comparable size. No vessel at all was found at the place where the pulmonary artery is normally located. The entire lung was uniformly more firm than usual although no portion of it was atelectatic. The pulmonary veins were normal in their location and course and, although small, entered the pericardium in the usual location. There was no evidence of any anomalous pulmonary venous drainage. There was no enlargement of the mediastinal lymph nodes. The right lung was removed. Postoperative course was uneventful.

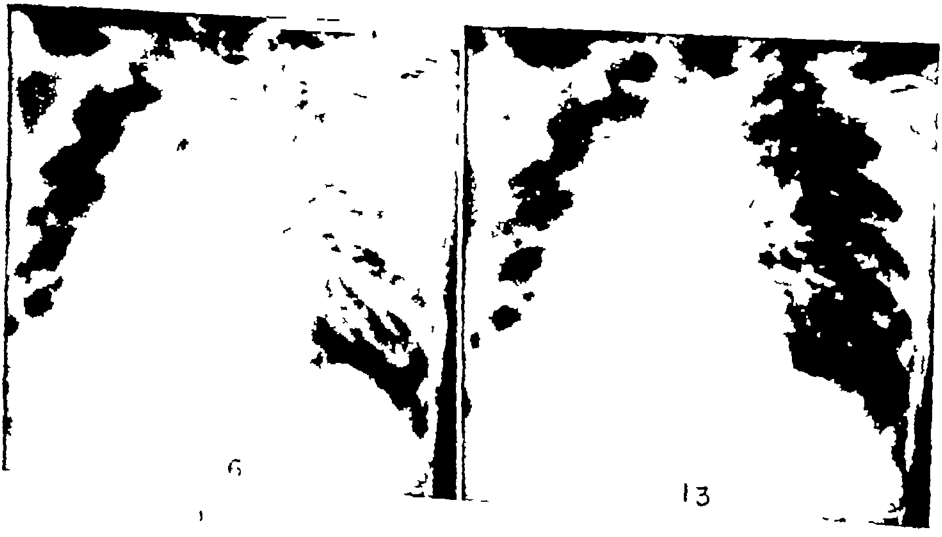
Microscopic examination of the excised lung revealed only slight dilatation of the smaller bronchi and very little evidence of inflammation. The striking finding was the uniform fibrosis of the lung with thickening of the interalveolar septa. This thickening was extremely uniform and not of a type usually seen with an inflammatory process.

Six months after operation the child was in good general condition but stated that he was slightly more short of breath than he had been prior to operation. It is too early to give a full evaluation of the result.

CASE 2.—A 37 year old woman did not complain of any respiratory or cardiocirculatory symptoms until six months previously. Two years ago the first roentgenogram of the chest had been taken because the patient was a food handler. This film showed the same findings as those taken two years later. During the past six months the patient complained of a tight feeling in the right side of the chest especially in the morning and had slight shortness of breath. She had only a slight cough but recently had had some mucoid sputum.

Physical examination revealed diminished respiratory excursion of the right side of the chest. The breath sounds were considerably less prominent on the right side as com

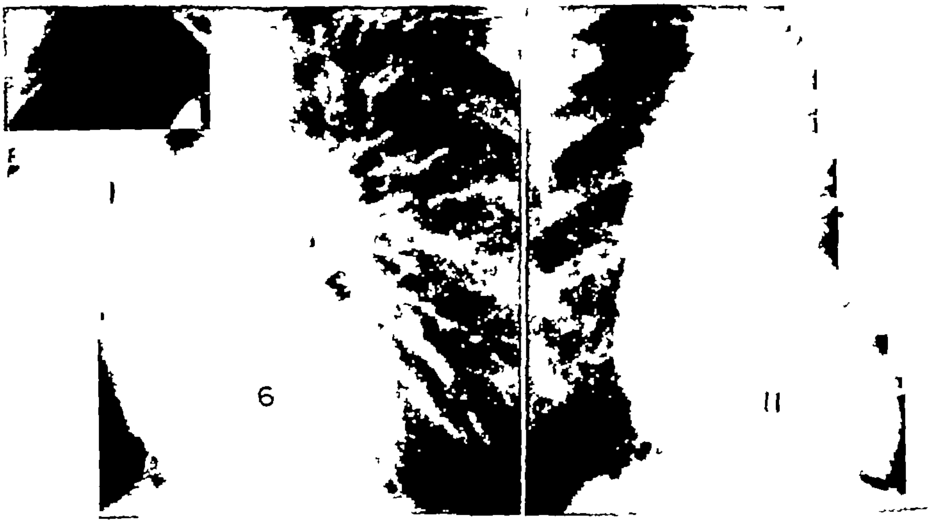
Fig. [illegible].—([illegible]) A, Roentgenogram taken at 4 years of age. Note slight mediastinal shift to the right. B, Roentgenogram at 9 years of age shows marked increase in mediastinal shift with elevation of the diaphragm, hyperinflation and herniation of the left lung with decreased aeration of the right lung.



[illegible] left pulmonary artery with [illegible] [illegible] after film in Fig. 2 shows [illegible] in the right lung. The tiny bronchial [illegible] visualized.

A B

Fig. 5.—Case 2. A, Posteroanterior roentgenogram shows the displacement of the mediastinum toward the right side, diminished aeration of right lung, and a large left pulmonary artery. There are fine infiltration and density at the right apex. This had been erroneously interpreted as a tuberculous process. B, Lateral view shows the anterior mediastinal herniation.



A B

Fig. 6.—Case 2. Angiocardiogram. A, A large left pulmonary artery is visualized. There is no evidence of any branch to the right lung. Note the absence of any opacification in the right lung field at this time. B, Two and a half seconds later the aorta is opacified and a thin network of bronchial vessels is delineated on the right side. Note the opacification of the density that had simulated parenchymal infiltration, demonstrating that these shadows were produced by blood vessels.

pared to the left where they seemed to be increased. No râles were heard. The heart was displaced to the right and the second pulmonic sound was slightly accentuated. Fluoroscopy showed diminished ventilation of the right lung with some mediastinal shift to the right on inspiration and diminished excursion of the right side of the diaphragm. The left pulmonary artery seemed larger than normal. There were small linear areas of density in the right lung most marked at the periphery near the apex. These shadows had previously been erroneously interpreted as old tuberculous infiltrates. The diagnosis of congenital absence of the right pulmonary artery was suspected on the basis of the roentgenogram (Fig 5 A and B).

Angiocardiography revealed absence of the right pulmonary artery and a large left pulmonary artery. The opacified blood did not enter the right lung until after the aorta had been opacified. The linear shadows in the right lung were demonstrated to be blood vessels which had filled from the aorta and represented hypertrophied bronchial arteries. These vessels remained opacified at the end of fifteen seconds (Fig 6 A and B).

No specific therapy was recommended.

CASE 7.—A 4 month old female infant was admitted to the hospital with the chief complaints of intermittent cyanosis, dyspnea and fever. Following a normal early postnatal period she had two episodes of cyanosis which were preceded by coughing and followed by vomiting which brought relief.

She was a well developed and well nourished infant. The skin was dusky gray. The respirations were rapid and fine râles were heard at the bases of both lungs. The heart appeared to fill the entire left chest, the rate was 180 and the rhythm was regular. The heart sounds were of good quality; a systolic murmur was heard over the precordium but was heard best in the third left interspace.

Laboratory examination revealed nothing unusual. Roentgenograms of the chest showed a greatly enlarged heart (Fig 7). The right hilar markings were more prominent than usual. There was an extensive area of increased density in the right lung field. The electrocardiogram did not show right axis deviation as would be expected in a child of this age.

Following digitalization the child was considerably improved and she was discharged with the primary diagnosis of congenital heart disease with failure. After two days of general improvement at home the infant again showed signs of acute respiratory embarrassment with a fever of 102° F. She was readmitted and now appeared acutely ill, dehydrated and had gasping respirations. There were moist râles throughout both lung fields, especially at the bases. The heart sounds had not changed except that the systolic murmur had increased in intensity.

The laboratory examination showed a slight increase in the white blood cell count with a normal differential. All other special examinations failed to reveal significant information. The patient's course became progressively worse and she died eighteen hours after admission.

Gross Findings.—The body was that of a well nourished well developed infant. The volume of the left lung was decreased by one half because of the enlarged heart. The interlobar fissures were normal in number and location. On sectioning the lungs scattered irregular hemorrhagic areas were noted throughout both lungs. There was frank consolidation of the right upper lobe. On microscopic study confluent lobular pneumonia was present in the upper and lower lobes of the right lung and the lower lobe of the left lung.

The greatly enlarged heart weighed 80 grams. There was equal dilatation and hypertrophy of [illegible] but the right was twice as [illegible] veins entered the auricles at their usual [illegible] the foramen ovale was patent. The pulmonary [illegible] The heart was otherwise [illegible]

[illegible] above the aortic valve a large [illegible] of the aorta. This artery crossed the [illegible]

The pulmonary artery was of normal caliber, measuring 2.5 cm in diameter at its origin and 1.7 cm in diameter beyond the dimple of the ligamentum. There was one branch to the left lung, but none to the right. Microscopic examination of the left pulmonary artery and the abnormal right pulmonary artery failed to show any difference in their mural structures.

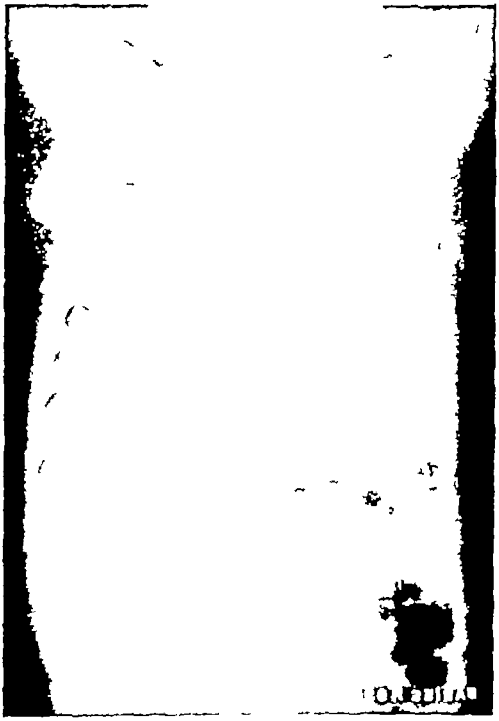


Fig. 7.—Case 3. Note the greatly enlarged heart and the increased vascular markings in the right lung.

HYPOPLASTIC LUNG WITH ANOMALOUS SYSTEMIC ARTERIES

Varying degrees of hypoplasia of a lung may occur. If the embryologic aberration is so extensive that a lung consists of less than the equivalent of a single lobe, it is unlikely that a clinically significant amount of normal respiratory tissue will be present. In the markedly hypoplastic lung congenital bronchiectasis and bronchial cyst formation usually constitute most of the maldeveloped lung. Even a unilobar lung with relatively normal pulmonary tissue is rare.[9] In an incompletely developed lung the pattern of the bronchial tree may vary widely and the single lobe in a unilobar lung may have a bronchial distribution which does not correspond to that of any normal lobe. Therefore it may be difficult to assess what the normal volume of a specific hypoplastic lung should be. The finding of emphysema and marked cardiac displacement to the involved side suggest that perhaps a small amount of pulmonary tissue has been overdistended.

CASE 4.—A 12 year old girl complained of being short of breath on exercise such as walking upstairs and riding her bicycle. The shortness of breath was said to have definitely increased during the past year. She had no history of pulmonary infection. When six months of age a chest roentgenogram was reported to have shown diminished aeration throughout the right chest with no lung markings distinguishable. The heart shadow was reported to be very indistinct and on the right side. Several years later a bronchogram was done. An anomalous right bronchial tree without evidence of bronchiectasis was demonstrated (fig. 8 A and B).

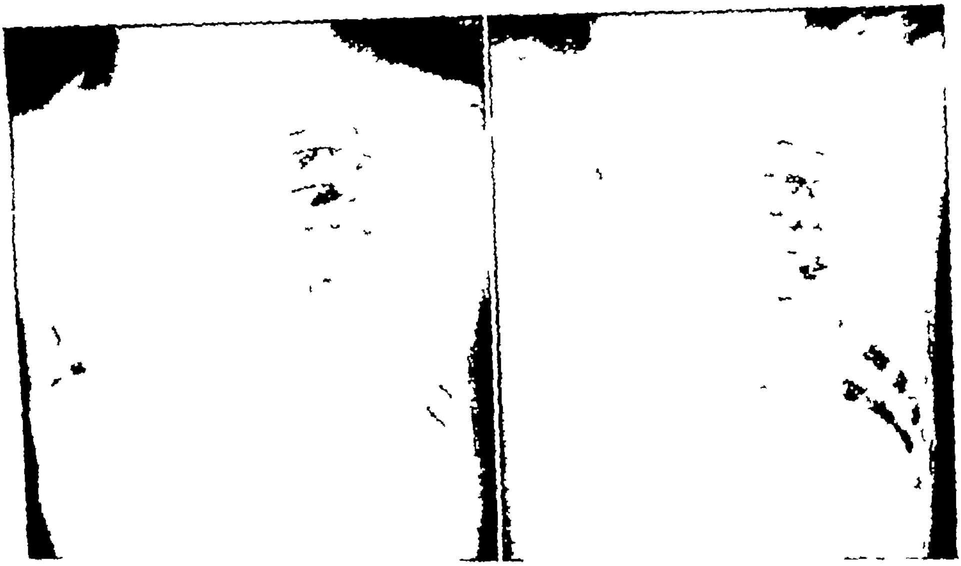


Fig. 8 (Case 4).—A, Roentgenogram at 4 years of age demonstrates dextrocardia and diminished size of the right lung. Note the vagueness of the cardiac outline. B, Bronchogram several years later showed an anomalous bronchial tree on the right side without bronchiectasis.

Since this girl had apparently more normal pulmonary tissue than following pneumonectomy and yet had more shortness of breath than one would expect in a 12 year old girl after pneumonectomy, it was considered probable that the pulmonary disability was due to [illegible] flow to one of the pulmonary tissue. Since the radiologic findings were very similar to those which had been seen several years earlier, it was considered probable that the [illegible] systemic arteries entering the hypoplastic right lung [illegible] were therefore recommended. This investigation was done through the courtesy of Dr Charles Dotter. The angiogram showed marked displacement and some [illegible] of the heart in the right hemithorax. There was a large left pulmonary artery and a small right pulmonary artery. After the abdominal aorta had been opacified, two [illegible] were visualized coursing along the medial aspect of the cupola of the [illegible] entering the base of the hypoplastic right lung (fig. 9 [illegible]). [illegible] there was prolonged opacification of [illegible].

[illegible] through the courtesy of Dr John West [illegible] of the Presbyterian Hospital. The vital capacity was [illegible] slightly reduced, the ratio of residual [illegible] Ventilatory studies showed a

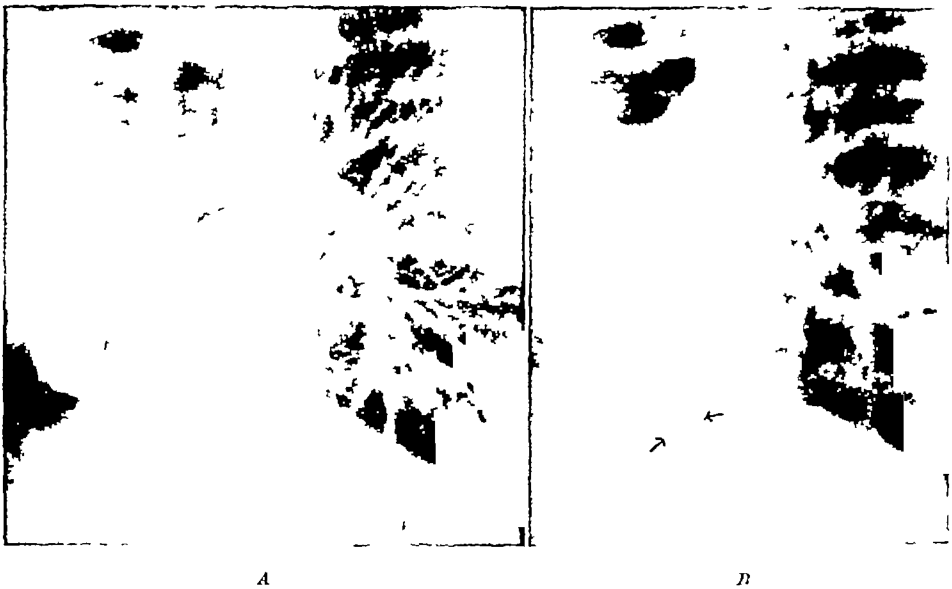


Fig. 9.—Case 4. Angiocardiogram. *A*, Demonstrating a large left pulmonary artery and a small branch to the right lung. The main portion of the right branch is superimposed on the left branch in this projection but some of the smaller branches can be seen going to the lower portion of the right lung. *B*, Later film with aorta opacified demonstrates two branches indicated by arrows entering the lower portion of the right lung.

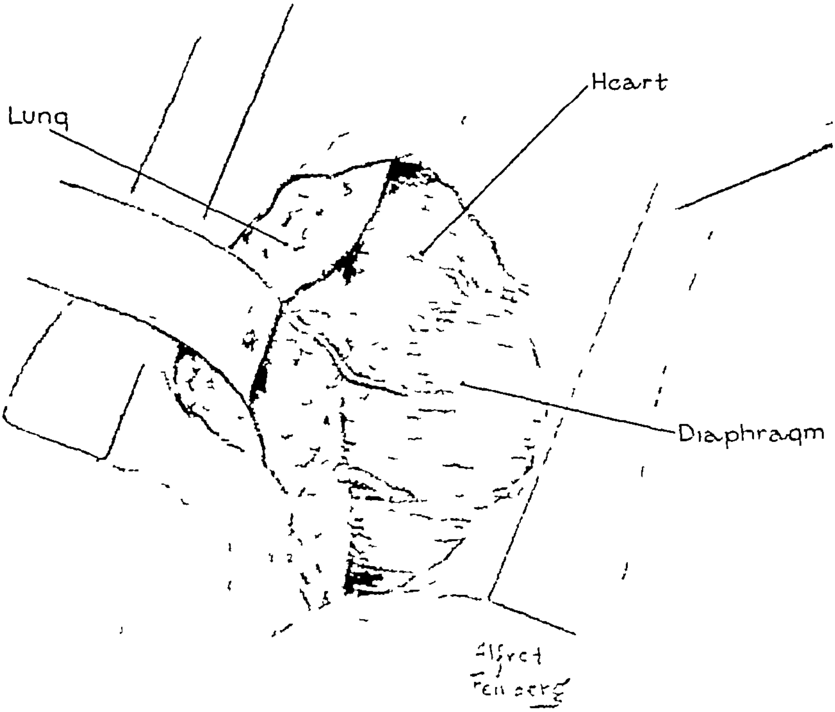


Fig. 10.—Case 4. Artist's drawing of operative finding. Note the two systemic arteries traversing the diaphragm and entering the base of the hypoplastic right lung.

slightly reduced maximum breath capacity but no evidence of obstructive breathing Some hyperventilation was seen at rest Studies of the gas exchange revealed normal arterial oxygen saturation and carbon dioxide tension both at rest and after exercise

In December 1951 the right hemithorax was explored There was no free pleural space except over a limited area of the lower posterior and lateral thoracic wall and a part of the diaphragmatic surface Here there was a well defined pleural space without adhesions and the reflection of the parietal pleura onto the lung at the border of this space suggested anomalous absence of the visceral pleura elsewhere Except for the pleural pocket mentioned the lung was diffusely adherent to the chest wall and mediastinum by areolar connective tissue which was traversed by some small blood vessels in a plane parallel with the surface of the lung The pulmonary tissue in general appeared normal There was no evidence of emphysema There was relatively little anthracotic pigment There was a systemic artery measuring about 6 mm in diameter perforating the dome of the diaphragm slightly posterior to the middle in an anteroposterior plane This artery entered the undersurface of the lung and then coursed along the lung tissue just beneath the surface and continued to have the thickness and anatomical characteristics of a systemic rather than a pulmonary artery A second systemic artery was found further posterior and somewhat more medial close to the vertebral bodies It too came through the diaphragm measured about 8 mm in diameter and divided into a small and large branch before entering the lung posteriorly in the paramediastinal portion (Fig 10) The further course of this artery in the lung was not visualized Both arteries which perforated the diaphragm had strong pulsations and obvious systemic arterial pressure A small lymph node was present at the site of entrance of each artery into the lung substance

The two arterial branches described above were dissected out, ligated and divided

The postoperative course was uneventful Since operation two and a half years ago the patient no longer complains of any shortness of breath and has continued to develop normally Radiographic examination of the chest shows no change from the preoperative appearance

CASE [illegible]—A 26-year-old woman had complained of dyspnea on exertion for seventeen years When 12 years old she had migratory joint pains and fever Even as a child she had been readily short of breath She had had occasional blood spitting during the past seventeen years usually in the form of pinkish mucus At one time she was admitted to a tuberculosis hospital but no tuberculosis was found It was known that her heart was in the right side of her chest

Physical examination revealed a thin poorly nourished woman without cyanosis Both sides of the chest moved equally on respiration but the heart was to the right of the sternum There was a rough systolic murmur at the base of the heart and a softer systolic murmur at the apex The electrocardiogram did not demonstrate the findings of a true dextrocardia Roentgenographic examination of the chest showed that the heart was displaced to the right of the midline and there was herniation of the left lung through the anterior mediastinum The lung fields were clear and the diaphragm moved normally There was no evidence of infiltration or atelectasis of the right lung Bronchographic examination demonstrated the bronchial tree of a right upper lobe which was overexpanded and extended downward nearly to the diaphragm but no bronchial tree of the middle or right lower lobes was outlined The bronchial tree of the left lung appeared normal At bronchoscopy [illegible] showed that the left main bronchus arose in an anterolateral [illegible] and the right main bronchus [illegible] in a posterolateral direction The right [illegible] but a short distance beyond this the bronchus nar[illegible] beyond this point was not possible It was [illegible] mass Biopsy of the bronchial [illegible]

[illegible] was revealed a [illegible]0 per cent reduction in [illegible] large residual air [illegible] was considerable hyperventilation at rest with a low rate of oxygen removal at rest which rose to almost a normal level during exercise The oxygen and carbon dioxide content of the arterial blood was normal during rest and exercise

A thoracotomy revealed no free pleural space The right hemithorax contained a unilobar lung The heart occupied a considerable part of the lower and anterior portion of the right hemithorax As the lung was freed from the diaphragm, several vessels were found penetrating the diaphragm close to the midline and entering the pulmonary tissue Two of these were systemic arteries and one of these two arteries was ligated and divided Both systemic arteries were not ligated and divided because it was not known at that time whether the lobe was also supplied by a pulmonary artery

CASE 6—A 14 year old boy had frequent upper respiratory infections and a persistent cough which gradually became productive of one half cup of yellowish sputum daily Although his activities were not seriously curtailed, he was moderately dyspneic on exertion One month prior to admission he began to complain of weakness and fatigue He coughed up a teaspoonful of blood at this time and again two weeks later

There was decreased expansion of the right chest with diminished breath sounds, dullness, and numerous rales on that side A rough systolic murmur was heard in the right second and third interspaces Roentgenogram showed a shift of the heart and mediastinum to the right, elevation of the right diaphragm, and intercostal narrowing on the right due to diminished volume of the right lung of long duration Bronchogram showed a well outlined bronchial tree of the right upper lobe, which was overexpanded The right main stem bronchus ended in a blind sac

At operation the right pleural cavity was obliterated by exceedingly dense and vascular adhesions There were several firm bands from the diaphragmatic pleura to the lower surface of the lung containing vessels measuring 2 to 3 mm in diameter There were no normal pulmonary arteries or veins on this side A large vein left the single lobe, ran parallel to the bronchus, and emptied into the superior vena cava The hypoplastic right lung was removed

Microscopic examination revealed diffuse emphysema with alveolar rupture throughout the lung parenchyma The pouch representing the undeveloped main stem bronchus demonstrated all normal bronchial elements

Two of the patients who had a hypoplastic, unilobar right lung with a small pulmonary artery and several systemic arteries going to that abnormal lung had rather similar findings (Cases 4 and 5) The older of the two had symptoms in adult life which it is hoped the younger will not develop because the anomaly was diagnosed and treated at an earlier stage It is my impression that the systemic vessels which entered the hypoplastic but uninfected and ventilating lung resulted in an augmented blood flow with high pressure to that lung It must be borne in mind that the situation was quite different from that which is created when a systemic artery is surgically joined to a pulmonary artery in order to increase the blood flow through the lungs in pulmonary stenosis In the latter situation the pressure in the pulmonary artery is not greatly elevated a short distance from the anastomosis unless secondary changes in the small pulmonary vessels have occurred[11] In contrast, however, are the findings when an anomalous systemic artery with its thicker wall conducts the blood into the pulmonary tissue At operation it was striking to note the way the pulsation of the small artery could be readily felt out into the smaller branches of the vessel The intravascular pressure was undoubtedly much higher than in a normal pulmonary artery I believe it is reasonable to assume that the dyspnea which was the first and chief complaint in these two patients was due to local pulmonary engorgement and that the patient's hyperventilation was produced by the same mechanism. The disappearance of any complaint of dyspnea in the patient who had the systemic arteries to the hypoplastic lung interrupted over two years ago supports this contention.

The two patients with a unilobar right lung, small pulmonary artery, and systemic arteries arising below the diaphragm had many unique features in common. The roentgen appearance in both cases was very similar. A striking finding was the degree of mediastinal displacement which was so marked that dextroposition of the heart was present. Moreover, the right heart border was not clearly outlined but merged with other shadows in the lower two-thirds of the right hemithorax (Fig. 8). The degree of cardiac displacement and rotation was much greater and dissimilar to that seen after surgical removal of the right middle and lower lobes. The small volume of the anomalous lung might be a combination of (1) being only one lobe, (2) reduced volume as a response to the abnormal systemic blood supply, and (3) pleural factors. In neither case did the visceral and parietal pleura appear normally developed throughout that hemithorax. The appearance simulated obliteration of most of the pleural space by adhesions but actually the lung tissue seemed to be attached to the chest wall by loose connective tissue. There was a distinct pleural pocket between the base of the lung and the diaphragm in one case but this pleura seemed to be merely reflected from chest wall onto lung at the margins of this pocket and not continued as a parietal pleura lining the hemithorax. Moreover, the surface of the lung did not present the usual surface markings or arrangement of bronchial vessels. Whether these atypical pleural findings contributed to the unique roentgen appearance can only be conjectured.

DISCUSSION

The blood flow from an anomalous systemic artery into a lung may be influenced by (1) size of the vessel and its branches, (2) character of the wall of the anomalous vessel especially in regard to its muscular and elastic components, (3) pressure within the vessel and the intravascular resistance, (4) degree and type of intercommunications with the pulmonary arterial branches when the pulmonary artery is not absent, and (5) nature of the venous system of the lung. Whether the neurogenic influence on the wall of such anomalous vessels is significantly different from that of normal pulmonary vessels is a matter for speculation. Moreover, there are no data concerning the effect of local oxygen tension on redistribution or shunting of blood as occurs in the normally [illegible] lung.

The [illegible] of blood flow from systemic vessels entering the lung must [illegible] importance. The larger the blood flow the greater the chances [illegible] hemorrhage and susceptibility to superimposed pul[illegible]

In [illegible] the anomalous systemic arteries to the lung from the aorta or its [illegible] like that of other systemic vessels [illegible] pulmonary arteries. Degenerative changes and atherosclerosis have been demonstrated in such anomalous vessels even in young individuals Aneurysm formation and rupture may occur Hemorrhage into the lung may occur [1 -] One of my adult patients had a long history of raising a pinkish frothy sputum The 12-year-old girl who complained of dyspnea on exertion was relieved of that complaint by ligation and division of the two systemic arteries which supplied part of the blood flow to her hypoplastic lung I have assumed that her sensation of dyspnea was due to a localized area of pulmonary congestion

SUMMARY

The pulmonary vascular plexus at one stage of embryologic development has important dorsal branches from the aorta which normally disappear These vascular communications with the aorta or its branches may persist when there is faulty development of the pulmonary artery

Although most recently reported cases of anomalous systemic arteries to the lungs have been discovered because of the associated presence of bronchiogenic cysts, bronchiectasis or sequestration of lung tissue, anomalous arteries from the aorta or its branches may enter grossly normal pulmonary tissue Anomalies of the bronchial branching and lobar development may also be present

The clinical features and the radiologic findings in cases of absence of the pulmonary artery to one lung are presented with illustrative examples

Two cases with a hypoplastic lung receiving a considerable blood flow through systemic arteries are discussed The effect of ligation of these systemic arteries is reported

The clinical and physiologic questions which anomalous vascular communications to the lungs present are briefly considered

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DISCUSSION

DR. JOHN S. HARTER, Louisville, Ky.—I wonder if Dr. Maier would consider the possibility of this type of case explaining the so-called capillary gear cell mechanism which was argued before this Association by Yates and Graham in one of the meetings in the early 1930's, that is, partial collapse of the lung due to lack of pulmonary circulation.

DR. CHARLES T. READ, Phoenix, Ariz.—I would like to discuss a case similar to the ones presented by Dr. Maier. This 8-year-old child was operated on two years ago and presented a combination of anomalies as did his cases. There were absence of the right pulmonary artery, agenesis of the right upper and middle lobes with hypoplasia of the right lower lobe, systemic artery supplying the hypoplastic right lower lobe with abnormal venous drainage into the inferior vena cava which produced a very marked vascular shunt thereby. In addition there were retroesophageal arteries producing marked dysphagia. The child had been a feeding problem all her life and was unable to swallow large boluses of food or firm food. There was also a patent ductus arteriosus on the left side.

The esophagram indicated creasing which would lead one to believe there was some blocking producing dysphagia. There is a rather bizarre type of bronchial distribution showing absence of the upper and middle lobe bronchi. The angiocardiogram shows the absence of the right pulmonary artery, and another view at a later stage shows the right ventricle, the left auricle filling.

Following the removal of a right hypoplastic lung associated with the numerous bronchovascular anomalies including an absent pulmonary artery, retroesophageal arteries, and systemic circulation of the right lower lobe, a patent ductus arteriosus remained on the left side. About four months after the first operation with only the left lung remaining, the patent ductus was approached through an anterior thoracotomy, divided and sutured. There was marked improvement in the patient after surgery.

So far as can be ascertained this is the first time the correction of a patent ductus has been accomplished with only one lung present.

DR. I. M. MADOFF, Boston, Mass.—I have enjoyed Dr. Maier's excellent paper. He has contributed a great deal to our understanding of these interesting pulmonary circulatory anomalies.

Dr. [illegible], Dr. Cressler, Dr. Lynch, and I have had occasion to study two patients with [illegible]. The first was a 14-year-old girl who was symptom free but this chest [illegible] an abnormal upper mediastinal shadow. Some of our studies on this patient [illegible].

Angiocardiography shows an absent right pulmonary artery with a normal and [illegible] left pulmonary artery. This patient was studied by bronchospirometric [illegible] and by cardiac catheterization.

The right lung was [illegible] to take up 7 per cent oxygen and the left lung took up 93 per cent [illegible] both lungs, the right lung took up no oxygen as opposed to [illegible] the left. [illegible] supplying oxygen to the right lung and room air to the [illegible] the right [illegible] per cent oxygen as compared to 82 per cent on the left. By [illegible] Dr. Robert Harrison, Lindskog, and Liebow of New Haven [illegible] that the effective bronchial circulation through the [illegible] of the [illegible] output of the left ventricle as opposed to [illegible] the bronchial circulation of the [illegible]

[illegible] and dyspnea. He had been [illegible] had had no external stigmata of [illegible] absent right pulmonary artery and a large [illegible] failure of the [illegible] circulation

[illegible] At [illegible] there was [illegible] of the aorta. This was [illegible] artery to the right lung and the bronchial arteries did not appear to be enlarged The parenchyma of the right lung was normal on microscopic examination, whereas that of the left lung showed marked atheroscelerosis of the pulmonary vasculature, apparently due to shunt Interestingly enough, this patient had clubbing of both feet and the left hand but not the right hand

The oxygen uptake of the right lung was 16 per cent, as opposed to the first patient, where it was 7 per cent, suggesting that where the circulation of the left lung was impaired, and the oxygen uptake was impaired, *the normal bronchial circulation of the right* lung would take up 16 per cent of the oxygen

DR DAVID H WATERMAN, Knoxville, Tenn —We have had the opportunity of seeing *two of the latter type of cases that Dr Maier described, of the rudimentary lung* and very small pulmonary artery Both cases were found on routine x ray surveys, and both were completely symptom free The first was an automobile mechanic doing heavy work and the other was a teen age boy who was a member of his local basketball team The x rays of both these patients looked very much like those of the patient shown by Dr Read, the pathology being on the right side in each instance I would like to ask Dr Maier if this condition is not more commonly found affecting the right side rather than the left

The amount of lung tissue present was exceedingly small In the first case a single lobe measuring 6 cm in length was encountered Pneumonectomy was performed In the second case there was a lower lobe, a rudimentary middle lobe with severe saccular bronchiectasis, and absence of the upper lobe In this case we resected the rudimentary middle lobe and ligated the systemic artery leading to the lower lobe, in line with Dr Maier's suggestion Both patients have continued to do well

DR HERBERT C MAIER (Closing) —I wish to thank the discussors With regard to the question of shrinkage of the lung being related to changes in circulation, I believe this is a very important and interesting correlation There is, as has been shown also by others who have ligated a pulmonary artery and left the lung in, a tendency for such a lung to reduce in volume I wondered whether some of the microscopic changes seen in the lung which we removed might not have been due rather to the circulatory derangement than to superimposed infection

These cases of absence of the pulmonary artery are considerably more common on the right side than on the left This is true whether the case is without heart disease, or whether you are dealing with cases where it is in association with the tetralogy of Fallot

SURGICAL RECONSTRUCTION OF THE SUPERIOR VENA CAVA

J. Gordon Scannell, M.D., and Robert S. Shaw, M.D. (by invitation)
Boston, Mass.

IT IS unusual to find superior vena caval obstruction that lends itself to surgical relief. The great majority of such cases are the result of inoperable malignancy, and for this x-ray treatment is our best recourse. There is, however, a small group of individuals in whom superior vena caval obstruction is the result of some benign process. As a general rule in the latter group the symptoms are not disabling or particularly distressing, but exceptions occur where the disability may be considerable and the discomfort intolerable, as in the two individuals reported here. For these patients reconstruction of the superior vena cava by means of a free vein graft is proposed.

In 1948 Gerbode and his associates[1] demonstrated in the experimental animal the feasibility of anastomosing the superior vena cava to the auricular appendage. In 1951 Klassen, Andrews and Curtis[2] described one patient suffering from superior vena caval obstruction in whom a free vein graft was placed successfully between the azygos vein and the right atrium in an effort to relieve obstructive symptoms. Other than these two, the literature contains only sporadic reports of attempts to relieve superior vena caval obstruction by operative measures, either decompression[3] or lysis of constricting scars.[4,5] Neither of these maneuvers would have been of value in the two patients reported here.

CASE 1.—A. C. (M.G.H. No. [illegible]) was a 57 year old man. Three years before his [illegible] had received x-ray treatment (3,500 r) to a right superior mediastinal [illegible] pressure symptoms (Fig. 1). Contrary to our established [illegible] been given without an actual biopsy. The immediate response to [illegible] The pressure symptoms were relieved for about one year [illegible] congestion of his head and neck so severe that he [illegible] occupation of carpenter. He complained of severe headache [illegible] The symptoms were entirely disproportionate to [illegible] that he had. X-ray films of his chest showed [illegible] tumor. The physical findings were those of the [illegible] The veins of the head, neck and arms were distended [illegible] and fullness of the neck. The pressure in [illegible] The extent of the venous collateral is shown in the [illegible] per cent dextrose was injected into the right

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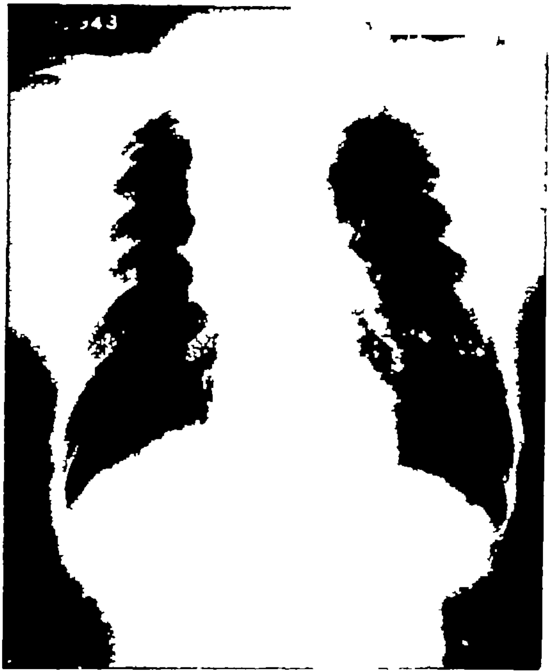
[illegible] Harvard Medical School and the [illegible] Surgical Service [illegible]

[illegible] grant from the National Heart Institute [illegible]

[illegible] The American Association for Thoracic [illegible]

Fig 1



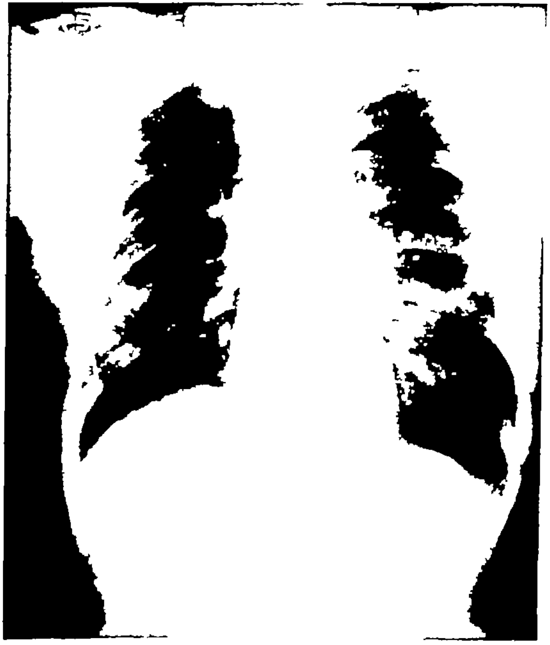


Fig 2

Fig 1—Case 1 X ray film of chest demonstrating mass in right superior mediastinum before response to x ray therapy three years prior to operation

Fig 2—Case 1 X ray film of chest taken one month after x ray therapy (3,500 r) showing marked regression of superior mediastinal mass Status was essentially unchanged three years later immediately prior to operation

Fig 3

[illegible] right antecubital [illegible]

[illegible]

antecubital vein (Fig 3), then into the left (Fig 4), and finally into a superficial femoral vein in order to outline the cardiac end of the superior vena cava (Fig 5). The lumen of the superior vena cava was completely obliterated at and above the level of the azygos vein. To provide symptomatic relief by improving the drainage from the superior caval system it would be necessary to re-establish continuity between a distal major vein and the right atrium, either the auricular appendage or preferably the intrapericardial portion of the superior vena cava. The severity of the patient's symptoms was judged sufficient to warrant operation, which was carried out on March 13, 1952.

The plan of operation is indicated in Fig 9. Through a median sternotomy incision the superior mediastinum and base of the neck were exposed. The superior vena cava and both innominate veins were encased in and obliterated by dense scar tissue. There was no

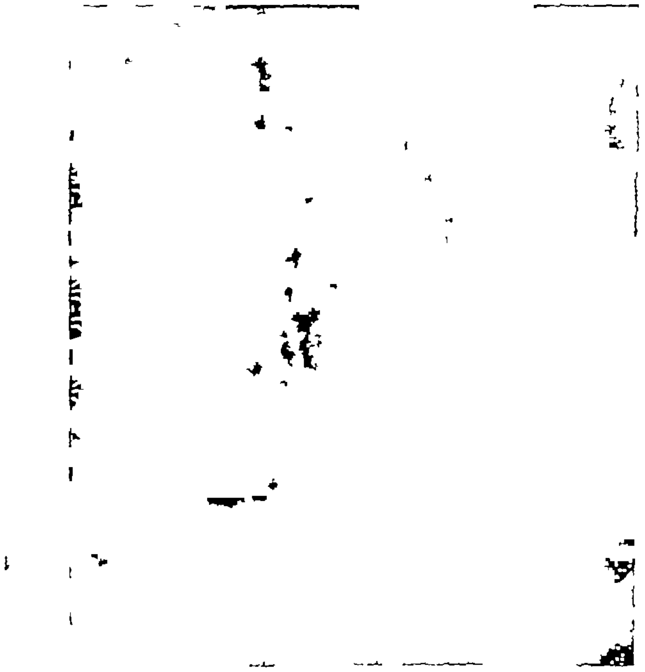


Fig 5.—Case 1. Venogram with 70 per cent diodrast injected into a superficial vein to demonstrate the intrapericardial portion of the superior vena cava by reflux of the dye from the right atrium. Auricular appendage cannot be identified with certainty.

evidence of residual tumor. Once through the skin and subcutaneous tissues there was remarkably little difficulty with venous bleeding. The key to the operative approach lay in the pericardial sac for within this sac the structures were virtually normal (Fig 6) and the intrapericardial portion of the superior vena cava was of generous length (see venogram, Fig 5). A free vein graft, in this case the superficial femoral vein taken from the same patient and transferred almost immediately to the chest, was used to bridge the gap between the right jugular vein and the right atrium (Fig 7, A and C). Dilute heparin solution was injected into the lumen of the vein graft. It was reasoned that anastomosis of one internal jugular vein to the atrium would carry sufficient blood from the head and neck to reduce the venous congestion in the region of maximum symptoms. It was further anticipated that this diversion of a sizable volume flow of blood would reduce the load on the already established collateral circulation and in this way reduce congestion in the entire superior vena caval drainage area as well.

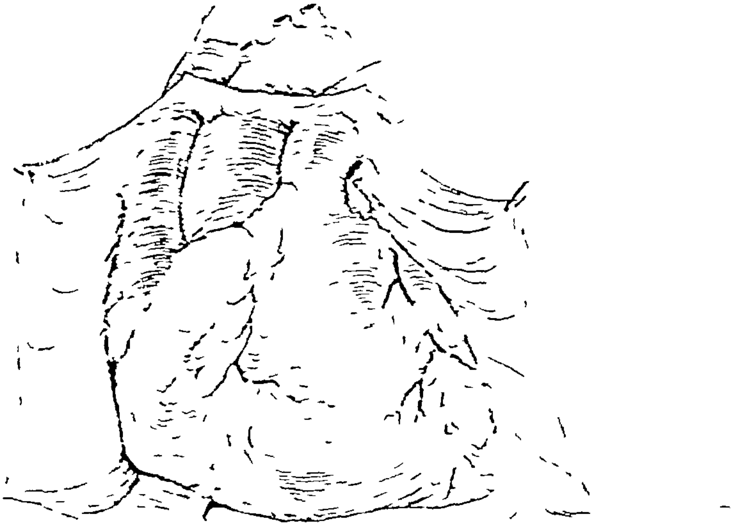
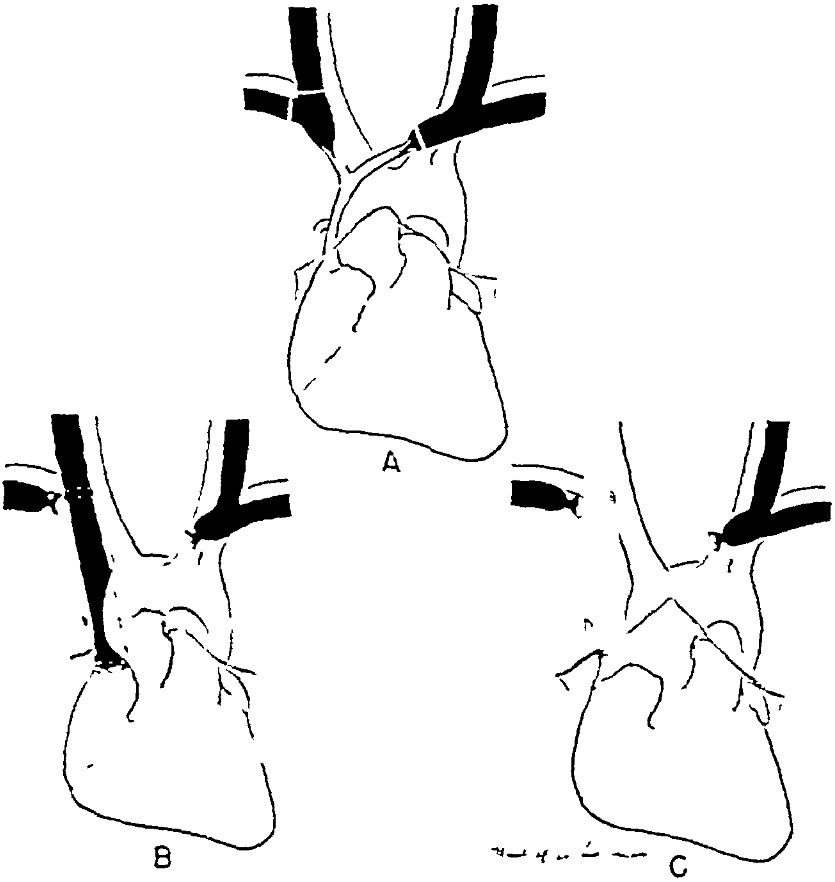


Fig. 6.—Drawing from autopsy observation showing the normal appearance of the su[illegible] cava within the pericardial sac. (After Holman et al.: Surg., Gynec. & Obst. 89: [illegible] 1949. By permission of Surgery, Gynecology and Obstetrics.)



[illegible]

The immediate postoperative course was gratifying Unfortunately, and certainly unwisely in view of the fact that the area had been previously irradiated, the sternum was closed without wire The closure proved to be unstable, and forty eight hours postoperatively partial dehiscence of the incision occurred In spite of resuture and the liberal use of antibiotics the patient developed an anterior mediastinitis and pericarditis from which he died on the eighth postoperative day Post mortem examination disclosed the important fact that *the vein graft, in spite of the mediastinal sepsis, was perfectly patent*

CASE 2 — E D (M G H No 631572) was 33 years old Twelve years before operation he had sustained a severe chest injury in a fall from a staging Two years later he began to suffer from choking spells, great congestion of his face and neck, and "black out" spells In 1948 the patient was first admitted to the Massachusetts General Hospital, and obstruction to the superior vena cava at the level of the azygos vein was demonstrated by venography and later by the passage of cardiac catheters (Fig 8) Operation was postponed until the technical details could be satisfactorily worked out The patient dropped from sight, but returned to the hospital in August, 1952, *with the complaint that his choking sensation and congestion were much worse and now intolerable* There was striking distention of the superficial veins of his face, neck, and arms He was unable to lie flat for more than a few seconds without appearing almost asphyxiated, nor could he bend forward while seated in a chair for more than 35 seconds without producing a frightful appearance of congestion The venous pressure in his right arm was 27 4 cm saline

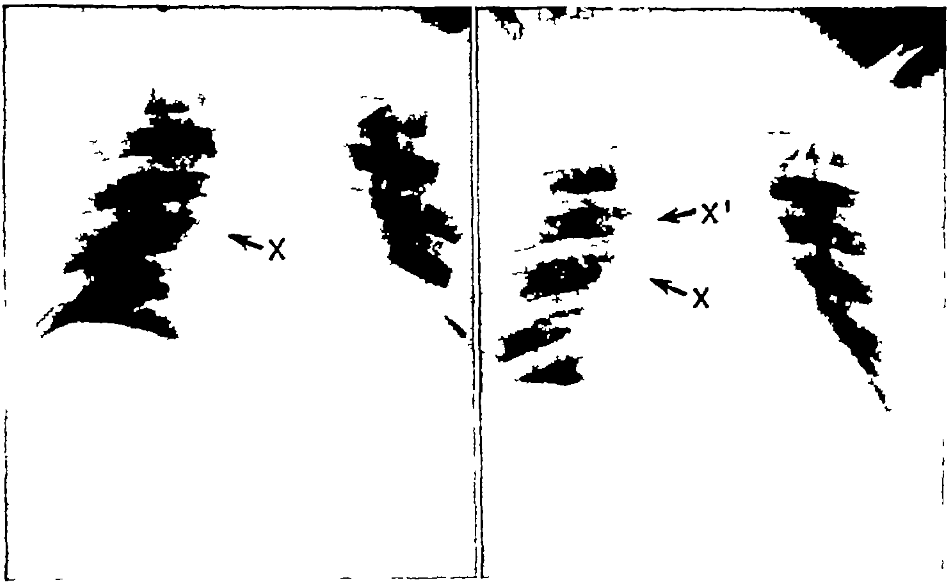
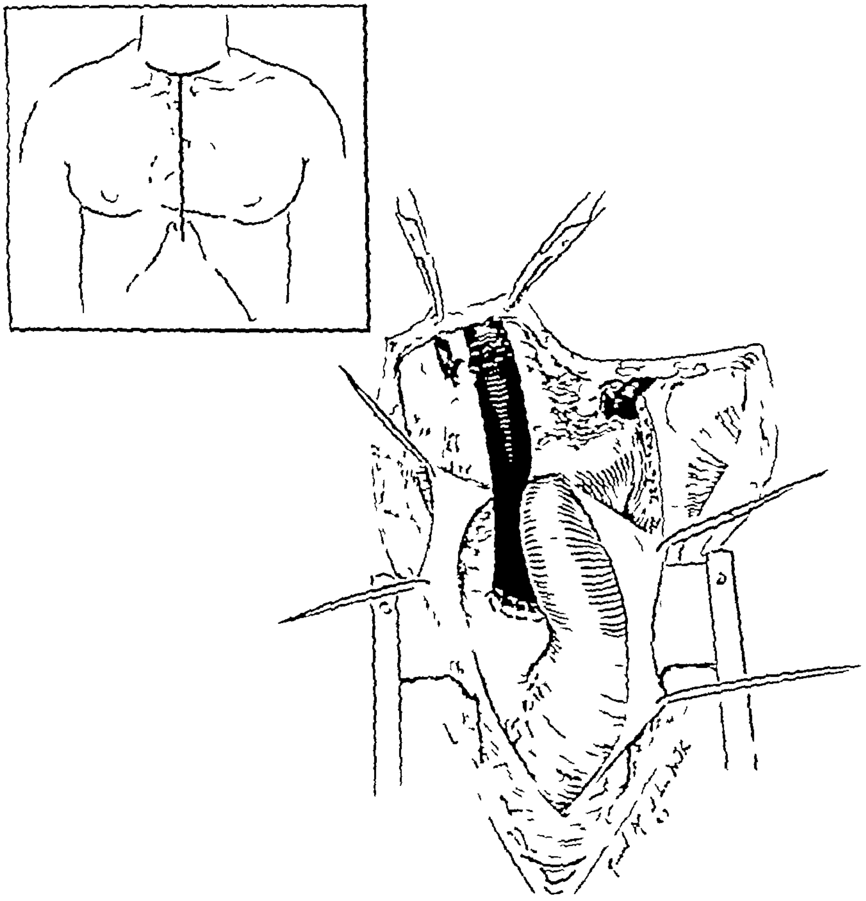


Fig 8 —Case 2 Preoperative chest films In the left-hand film a cardiac catheter has been introduced by way of a saphenous vein to the level marked X In the right-hand film the lower limit of the innominate vein is demonstrated by a catheter introduced into the right antecubital vein (X') Venograms were unsatisfactory for reproduction

Operation was carried out Sept 11, 1952 The plan was basically the same as in Case 1 except that in this case it was necessary to implant the cardiac end of the vein graft into the tip of the right auricular appendage (Fig 9) The latter was easily controlled with a soft, noncrushing clamp Dilute heparin solution was used locally No anticoagulants were used postoperatively

In this second case great difficulty was encountered with venous collateral and dense scarring of the superior mediastinum Scattered calcification throughout the scar suggested that the pathologic process was an organized hematoma of the superior mediastinum traceable to the original chest injury.

Though complicated by atelectasis the patient's course was satisfactory and he was discharged on the seventeenth postoperative day. The patient returned for evaluation three months later. Subjectively he had improved greatly. He could sleep flat without choking distress or nightmares. He could bend over to tie his shoes or to take things out of a lower drawer—a motion necessary to his occupation as a salesman in a jewelry store. He could lie flat on the examining table quite comfortably and with minimal congestion of his face. Three minutes after bending over while seated in a chair his face appeared red but not abnormally



[illegible] Operative [illegible] [illegible] anastomosis [illegible] [illegible] sutures of [illegible] silk was used. A combination of [illegible] The anatomic [illegible] to the upper limits of the pericardium is [illegible]

[illegible] only slightly lower than the pre[illegible] [illegible] changed significantly since operation did not directly [illegible] of the vein graft was ob[illegible]

[illegible] operatively. The general clinical impression at

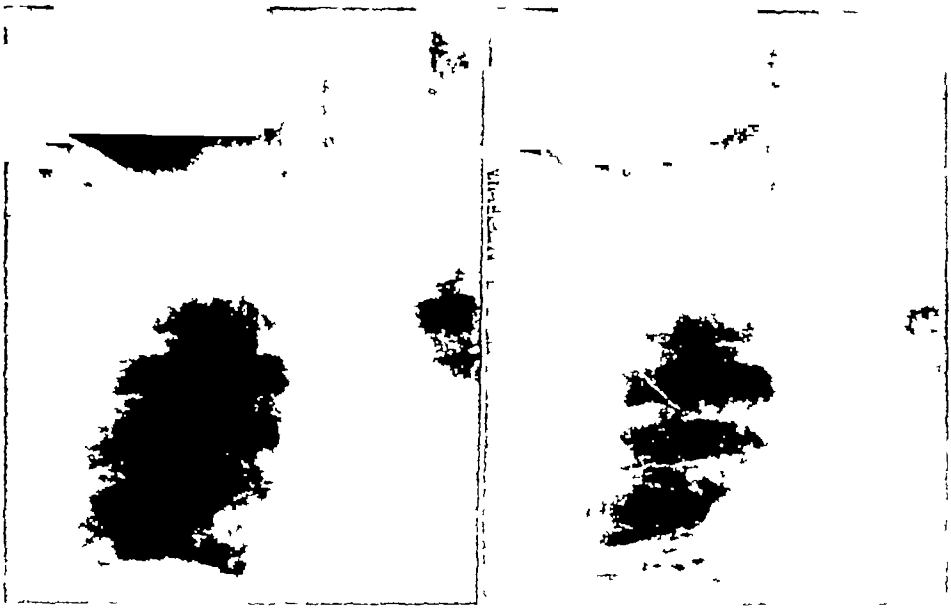


Fig 10—Case 2 Venogram three months postoperative Diodrast injected into right internal jugular vein percutaneously Films taken at approximately one half second interval showing passage of dye through graft and prompt clearing of opacity Slight constriction evident at level of upper suture line

CONCLUSION

So far as we are aware, these two cases, plus the one somewhat similar case reported by Klassen et al, are the first patients in whom a direct attempt to relieve superior vena caval obstruction by free vein graft has been carried out Credit for many of the details of the technical approach must go to Gerbode and his associates It is unlikely that the procedure will have wide application, but in the occasional case where the symptoms are sufficiently distressing and disabling, and where a benign or stationary basis for the obstruction can be shown, it appears to be logical and justifiable

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DISCUSSION

DR PAUL C SAMSON Oakland Calif—I think Dr Scannell should be congratulated on these two cases and on carrying experimental work into the clinical field Such cases represent a small but growing number of patients in whom significant clinical mediastinal lymphad cavitis is manifest. I have been particularly interested in this problem because the vascular system is involved as well as the tracheobronchial lymph nodes.

My own case was not entirely successful but luckily I had the opportunity of talking with Dr Frank Gerbode at some length before treatment was attempted. This 18 year old man entered the hospital in November 1948 about three weeks after having had a tooth pulled. I do not know the significance of that. There was rapid development of weakness, of swelling in the upper extremities and the face, fever and pallor and cyanosis.

No lymph nodes were seen by x ray. For three months the patient was treated by an internist, chemotherapy and bed rest, and several x ray treatments were given because of the presumed diagnosis of lymphoma. We did not see him until just before surgery. His venous pressures were consistently elevated from 200 to 400 mm of water. The obvious obstruction continued and then May 14 1949 an anterior mediastinotomy was done which revealed a great amount of scar tissue and many large and small lymph nodes matted together. Some of them contained caseous debris. There was actually a rosette of nodes around the entrance of the superior vena cava into the pericardium. Following our discussion with Dr Gerbode we used an autograft of superficial femoral vein end to end above and end to side below. This was not completely successful. Although there was considerable relief of the symptoms no particular diminution in the venous pressures had occurred five months following operation.

Something happened in the venogram which I cannot explain. The azygos system was full postoperatively but did not fill preoperatively. Time will not permit the discussion of everything we learned from this case. If however I had to do such a case again I would do a posterior right thoracotomy incision instead of anterior mediastinotomy, because I believe that, in certain cases at least the azygos vein may be used as a swing up graft rather than to use a completely separate autograft.

DR T [illegible] O NEILL Philadelphia Pa —I should like to comment on this paper briefly and to present two patients who had superior vena caval obstruction due to benign lesions.

The first patient had had symptoms of complete obstruction for a period of twenty years. The original diagnosis was said to have been tuberculosis but it was never proved and on the phlebogram we can see obliteration of the superior vena cava and its two major confluences and a lesion in the lung. This patient has a pressure of 15 cm in the upper veins. She was recently admitted to the hospital. There is tremendous swelling of the head and arms. It would appear that she will be a candidate for vein graft such as Dr Scannell has so well outlined.

The next patient was an instance of almost complete obstruction of the superior vena cava. This woman had symptoms for almost ten years. The symptoms began after an exploratory [illegible] elsewhere on the right chest. The operative report was not complete [illegible] mentioned and the only thing we could tell was that apparently there was [illegible] the right [illegible] as the dye outlined the left pulmonary artery well and [illegible] the right side. There was a tremendous woody mediastinitis present. An exploratory [illegible] and it was found that an obstruction existed in this area. It was [illegible] graft [illegible] necessary. The vein was opened and the well organized scar [illegible] removed from the inside of the vein, the vein was reconstructed [illegible] of symptoms over the past year. I think there is a possibility of [illegible] patients who have a short length of obstruction. Where a [illegible] vein graft will be the only permanent solution.

DR EARLE B KAY Cleveland Ohio —I should like to comment on this paper not from [illegible] failure. Following Dr Gross's work in 1948 we performed [illegible] caval transplant might work [illegible] The vena cava was taken from one dog and [illegible] the auricular appendage of [illegible] graft in [illegible] the

We have here an example of a patent vein graft at twelve days By six months all the grafts showed varying degrees of sclerosis At the time the dogs were sacrificed none showed what we would describe as good grafts

During the period of initial success three patients with superior vena caval syndrome secondary to chronic fibrosing mediastinitis were operated upon The first patient died postoperatively following a transplant taken from another individual dying in an accident, which was anatomosed between the innominate veins above and the auricular appendage below The second patient had a preoperative venous pressure of 45 cm of saline An anastomosis was made between the azygos vein and the auricular appendage Postoperatively the pressure dropped to 15 cm of saline There was gradual return of the venous pressure to the preoperative level The patient died four months postoperatively The anastomosis had sclerosed The third patient, with a similar condition, had a superficial femoral vein transplanted between the innominate veins at their junction and the auricular appendage That patient is alive today, about five years later, but there is evidence that the graft is not functioning From our experience we would state that the homologous or autogenous transplantation of veins in the treatment of superior vena caval syndrome secondary to chronic fibrosing mediastinitis is not successful

DR ROLLINS HANLON, St Louis, Mo —I would agree in general with the criteria of Dr Scannell and his associates that this procedure should be employed in benign conditions in which the patient's symptoms are severe But I would like to suggest that there are circumstances in which, with a malignant obstruction, even an irremovable malignancy, the symptoms may be so severe that it might be considered expedient to carry out a palliative shunt That was the circumstance in a 65 year old man whom we saw four years ago, who presented the picture described by Dr Scannell of such severe vena caval obstruction that he was unable to remain in any position except bolt upright, the slightest tendency toward recumbency produced alarming signs and symptoms For that reason, with a working diagnosis of malignancy, we explored him through a combined sternotomy and intercostal incision The diagnosis of malignancy was confirmed, the condition was an irremovable malignancy with infiltration of the entire dorsal surface of the vena cava from its origin down to and including the intrapericardial portion For that reason it was not possible to circumscribe the superior vena cava at any point so as to excise the involved area and replace it by a graft between its cut ends We therefore placed an aortic graft with its caudal portion anastomosed to the tip of the right auricular appendage and its cephalic end placed tangentially into the ventral surface of the superior vena cava

End to end anastomosis of the graft to the right auricular appendage was done and a button of the ventral wall of the cava was excised distal to a curved Potts multitoothed clamp, applied tangentially The graft was preserved according to the original technique of Gross Bill, and Peirce and was kindly furnished by Dr Peirce

The graft carried blood around the obstructed area As soon as the clamps were removed there was a striking decrease in venous tension in the upper part of the body

The angiogram confirms the patency of the graft, one may see contrast substance flowing through it and appearing promptly in the pulmonary artery

The patient was promptly relieved his venous pressure fell from a preoperative level of 20 mm of saline to 180 a few hours after operation and to 100 some days later He lived for about four months and, despite x ray therapy, the graft remained patent as judged by a persistent murmur

DR KARL P KLASSEN Columbus, Ohio —We agree with Dr Scannell that most of these cases of benign constricting type of occlusion of the superior vena cava, whether produced by tuberculosis or fungus infection do not require treatment However, we did have two patients who did require treatment because of the severity of their symptoms The first one was mentioned by Dr Scannell This patient is still in good health, his pressure, however, has not returned to normal We believe the graft to be patent although we have not proved this by venography It was proved patent when this patient was reported in 1951

The second patient had severe symptoms produced by a benign constricting lesion of the superior vena cava. The obstruction extended over a distance of about 10 cm. and a vein graft could not be applied. For this reason we elected to use a preserved aortic homograft. This was used to replace the vena cava with immediate return of flow through this channel and a fall in the venous pressure in the upper extremities. However, one month later this graft clinically became thrombosed. The patient is all right two years later; his graft is not functioning. He has developed more extensive collateral circulation and is able to carry on as a laborer.

DR. RALPH A. DETERLING, New York, N. Y.—We also anticipated a need for an occasional replacement of the superior vena cava and late in 1951 Dr. Vance Lucas and I carried out some experiments on dogs, excising segments of superior vena cava and implanting aortic homografts preserved in a nutrient electrolyte solution at 4° C. A series of animals prepared in this manner were followed by angiography and in no instance was there a disappointing result. Microscopically there was disappearance of the cellular elements of the graft; there was excellent epithelization and the suture line looked quite good. In some instances after a long period there was corrugation of the graft.

One graft was maintained in a dog for seven months to demonstrate such a change. Then for two years we awaited a patient for whom this might be suitable. We explored a number of patients with caval obstruction who turned out to have carcinoma of the thymus, Hodgkin's disease, or aortic aneurysms. Finally, in January, 1954, we saw a 26-year-old woman who had been treated for angioneurotic edema for eight months with moderately severe symptoms. She had a pressure in her brachial veins of 200 mm. of water. A venogram showed complete obstruction of the superior vena cava, and on January 12 we explored her very adequately through a right posterior incision as suggested by one of the discussors.

A preserved aortic homograft was used to bridge a 6 cm. defect after excision of an obstructed segment of vena cava. The obstruction resulted from an old tuberculous lymph node. The graft was anastomosed to the intrapericardial portion of the vena cava adjacent to the auricle as shown in this area. We contemplated using the tip of the appendage as suggested by Gerbode and his group, but the motion was very active and we feared that thrombosis might occur. The results so far after five months have been very satisfactory. Anticoagulant drugs were not used.

DR. FRANK L. GERBODE, San Francisco, Calif.—I should like to congratulate Dr. Scannell on the excellence of his presentation and also upon his ability in finding two patients with correctable caval obstruction. We have searched for these patients rather diligently and find that they are extremely scarce.

I thought you might like to know what has happened to some of the experimental work that Dr. Scannell and others have mentioned. We have now followed some of the animals that had superior and inferior caval shunts for more than five years. I can give you the results [illegible] after that period. In a superior caval shunt, the superior vena cava was [illegible] and appears smooth and after two and a half years. In [illegible] inferior vena cava was detached from the right atrium and made [illegible]. A small line is the only evidence of the suture line. If such a shunt [illegible] it apparently will stay open forever.

[illegible] about [illegible] all we used homografts very much as sug[illegible] [illegible] experimental defect in the superior vena cava. In every [illegible] graft thrombosis or gradual fibrosis occurred. We [illegible] narrowed down in time. As I have stated [illegible] systemic blood pressure is nece[illegible] [illegible] replace the graft. Venous pressure is not great [illegible] I do not think using a homograft is the answer.

[illegible] of the caval shunt can be applied that of [illegible] In order for this situation to be compatible with life a patent foramen ovale must be present to allow the blood to pass to the left side of the heart. The auricular appendage lies conveniently and is of large size making a side-to-side shunt feasible. We attempted to shut off the cava after the shunt was completed but the heart did not seem to tolerate this too well. The child has done extremely well, is growing normally, and although we cannot say for certain that the shunt is functioning, her clinical course has been excellent.

DR. C. W. HOLMAN (New York, N. Y.).—I should like to comment about a patient on whom we did a shunt procedure using a preserved arterial aortic graft. The reason for reporting this is because I thought that a preserved arterial graft would be superior to a vein graft.

I think from the discussion of Dr. Gerbode and Dr. Klassen it seems that possibly a vein graft is superior to the aortic graft which we used. This venogram tells the story of the obstruction of the superior vena cava in the region of the right innominate vein. Here is a sketch of what was found in the angiocardiogram. At operation we found a condition typical of the mediastinitis reported by Erganian and Wade. The left innominate was lost in the process, the obstruction extending to the right innominate vein. Here is shown the aortic graft in place. The pressure dropped from the preoperative level of 300 mm. of saline to 110. Along the lines of Dr. Gerbode's and Dr. Klassen's comments, the venous pressure is now increased to about 180 mm. after a period of about six months. This shows the angiocardiogram after insertion of the aortic graft. The patient is completely asymptomatic.

DR. J. GORDON SCANNELL (Closing).—I would merely like to thank the discussers. I have nothing to add.

PULMONARY BLASTOMYCOSIS

A Critical Analysis of Medical and Surgical Therapies, With a Report of Six Cases

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A RATIONAL and optimistic therapeutic approach to pulmonary blastomycosis is now possible. A safe effective chemotherapeutic agent is available and pulmonary resection may be employed when indicated. This report will review the accumulated experience with stilbamidine and 2-hydroxystilbamidine therapy and will analyze the reported (20 cases) and personal (6 cases) experience with pulmonary resection in this disease.

The hyphomycete *Blastomyces dermatitidis* causes cutaneous and visceral lesions with equal frequency.[1] Gilchrist[2, 3] in 1894 first described the disease in its cutaneous form. The dermatitis is relatively benign but the mortality in *recognized* cases of visceral disease has, until recently, been approximately 90 per cent.[4] The lungs are involved most frequently, then the skeletal system, but lesions have been found in every organ and tissue of the body.[4, 5] There is evidence that the lung is the portal of entry at least in the systemic disease.[4] There is pathologic evidence that even without specific therapy there is a strong healing tendency in the lungs. It is probable that unrecognized and self-limited cases have occurred.

INCIDENCE

Blastomycosis is not uncommon in some localities although it is generally considered a rare disease. It has been reported almost exclusively from North America but cases have been reported from China,[6] England, Australia,[5] and recently in epidemic proportions from Okinawa. Early in the century the disease was reported most commonly from Chicago and the Midwest.[4, 10] Subsequently numerous cases have been reported from Cincinnati, Buffalo,[11] New Orleans, Memphis, and Durham.[3] In 1939 Martin and Smith[4] collected 243 proved and presumptive cases.

The disease is being recognized more frequently. Seabury[14] has seen and treated 12 cases of systemic blastomycosis at the Charity Hospital in New Orleans in the last two and one-half years. In 1949 Smith[3] reported that 30 cases had been studied in the Duke Clinic in the past eighteen years. Seely and

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[illegible] of The American Association for Thoracic [illegible]

[illegible] New Orleans, La.

Smith[1] report that they have recently seen from a single small community in eastern North Carolina 8 cases of pulmonary blastomycosis, three being children living in the same block. Between 1951 and 1953 White and Owen[16] resected 4 unsuspected lesions of pulmonary blastomycosis in the comparatively small city Huntington, West Virginia (pop. 80,000).

The incidence of the disease to a large degree parallels the interest and suspicion of the medical profession of a locality. Snapper and McVay[13] reported 16 cases, 5 cutaneous and 11 systemic, seen at the John Gaston Hospital in Memphis over a ten-year period. With increased medical interest in the disease 7 additional cases were seen in the subsequent fifteen months. Hughes and co-workers[1] report an almost fourfold increase in the diagnosis of all pulmonary fungus diseases at the Kennedy Veterans Administration Hospital in Memphis since 1949 when the staff became interested in the problem.

CLINICAL PICTURE

Pulmonary blastomycosis most commonly develops as an indolent chronic infection causing systemic symptoms of fever, malaise, night sweats, and weight loss, as well as thoracic symptoms such as cough, sputum, hemoptysis, dyspnea, and chest pain (Table I). The pulmonary infection may be protean in its manifestations. Cases of acute and subacute pneumonia have been observed.[15] We have observed an acute blastomycotic lung abscess in a 12-year-old boy. There may be associated lesions in the skin, the subcutaneous tissues, or the viscera.

TABLE I. PRESENTING SYMPTOMS IN 6 CASES OF PULMONARY BLASTOMYCOSIS TREATED BY RESECTION

CASE	COUGH	TEMPERATURE	CHEST PAIN	HEMOPTYSIS	MALAISE	WEIGHT LOSS (LB.)	DURATION OF SYMPTOMS	SKIN LESIONS
1		102°	+		++	11	2 mo	
2	+	102°		+	+	20	7 wk	
3	+		+	+			27 mo	
4	+	101°					3 mo	
5	+	101°	+	+	+	21	2 mo	
6	+	101°			+	10	12 mo	+

PATHOLOGY

Schwarz and Baum made a careful pathologic study of 20 cases of pulmonary involvement from Cincinnati and the Armed Forces Institute of Pathology. They classified the lesions into three groups. (1) Seven cases presented primarily an exudative pneumonia without granuloma formation. Alveolar destruction was common but major abscess formation was rare. Blastomycetes were frequent. (2) Four cases consisted chiefly of granulomatous lesions with epithelioid cell tubercles. Giant cells were a prominent feature. Yeast cells were less frequent. (3) In 9 cases mixed exudative and granulomatous lesions were present. A pleuritis was found in all cases in which pleura was available for examination but the absence of pleural fluid was notable Endobronchial lesions chiefly in the smaller bronchi were seen in all but one case A tendency to scarring was seen repeatedly and was interpreted as evidence of healing Cavities were not observed but focal necrosis occurred in the center of large exudative foci

Martin and Smith[4] report that the pathologic picture is quite variable They describe diffuse or focal consolidation which may simulate miliary tuberculosis or there may be larger nodules or abscesses distributed through the organ They state that cavities occur but that they rarely exceed 1 cm in size Caseation is described frequently in small foci

In view of the repeated pathologic observations that large cavities do not occur it is interesting that in our Case 3 J R T the presenting lesion was a cavity in the left upper lobe which enlarged over a two year period and at resection measured 4 cm in diameter Our Case 6 C McC, developed cavitation and complete destruction of the left lower lobe although advanced bilateral disease was otherwise controlled by 2 hydroxystilbamidine therapy Feld and Cadden[12] report in two cases cavities measuring 5 and 7 cm in diameter Murphy[illegible] resected a right upper lobe for a 2 cm cavitary lesion thought to be an abscess He has treated a second case medically for bilateral cavitary disease Seabury[11] has treated a case with a destroyed right upper lobe two large cavities in the apex of the right lower lobe and multiple cavities in the upper and lower lobes on the left (see Case L M) Tissue destruction and cavitation occur less frequently than in tuberculosis but extensive necrosis and cavitation may occur

The disease may involve the chest wall directly or by metastasis but there is little tendency for cutaneous fistula formation so commonly seen in actinomycosis Generalized spread throughout the body may be expected at any time The fungi have been seen repeatedly in the blood vessels and this is the route of spread of the disease[illegible]

DIAGNOSIS

The problem of correctly identifying a lesion in the lung is the same in blastomycosis as in *other* pulmonary disease Awareness of the disease is an essential prerequisite for a correct diagnosis The clinical picture is not diagnostic Even when one is aware of the possibility and uses every test at his command correct preoperative diagnosis is often difficult

Roentgenography—There is no characteristic pattern Every type of picture from widespread bilateral disease to solitary coin lesions has been seen Since the disease is a granuloma it must be considered with and differentiated from tuberculosis coccidioidomycosis moniliasis histoplasmosis and torulosis[illegible] Three of our cases were thought to be inflammatory two neoplastic and one cystic disease

Bronchoscopy—Weed and Landis[illegible] have reported seven consecutive cases of blastomycosis with endobronchial disease The characteristic findings were [illegible] mucosal erosions and glairy thick brown mucus One case

TABLE II. TABULATION OF REPORTED AND PERSONAL CASES OF PULMONARY BLASTOMYCOSIS SUBJECTED TO RESECTIONAL THERAPY

AUTHOR DATE	PATIENT	AGE	COLOR SEX	PREOP. DIAGNOSIS AND TREATMENT	RESECTED SPECIMEN	POSTOP. TREATMENT	RESULTS
Smith 1949	M. M.	47	WF		Lobe	KI	Died 2 years after resection of disseminated disease
Smith 1949	J. F.				Lobe	KI	No follow up
Webb 1949		38	WM	Undetermined	Right lung	None	Died day after surgery
Field, Caldwell 1949	J. S.	30	WM	Blastomycosis, KI	Right upper lobe	KI	Died 11 months postop. of disseminated disease
Good et al. 1951		39	WM		Lobe		No follow up
Lowry et al. 1951	W. C. B.	30	NM	Pulmonary cyst, no treatment	Right lower lobe	None	Five years follow up, patient well*
Hopkins and Murphy 1952	A. K.	31	NM	Blastomycosis, no treatment	Right lung	KI	Died 6 months after resection of disseminated disease
Hopkins and Murphy 1952	A. D.	40	WM	Carcinoma, no treatment	Left lung	KI 6 weeks undecylenic acid	Developed widespread skin dissemination treated with undecylenic acid alive and disease free 2 years later
Weed and Landis 1953	G. H.	27	WM	Undetermined, no treatment	Right lower and middle lobes	None	Three years and 10 months free of disease*
Weed and Landis 1954	H. B.	50	WM	Undetermined, no treatment	Right upper lobe	None	Four years free of disease*
Buechner et al. 1953	A. P.	50	NM	Undetermined, no treatment	Right lower lobe	None	Two years free of disease*
Buechner et al. 1953	J. J.	40	NM	Undetermined Strep. P.A.S. 3 weeks	Right upper lobe	Human serum KI 2 hydroxystilbamidine	Residual disease. Rib and transverse process involvement. Thoracoplasty responded to medical treatment. Well 18 months later
Cummins et al. 1954		39	WM	Carcinoma	Right upper lobe	KI stilbamidine	Developed skin lesion. Well 2 years

[illegible]	[illegible]	[illegible]	WM		Left upper lobe		Thirty-three months free of disease
[illegible]	C. N.		NF	Blastomycosis Blastomycin	Left upper lobe	Blastomycin KI	Contralateral spread responded to medical treatment. Well 3 years after surgery
[illegible]	E. H.	41	NM	Blastomycosis blastomycin	Right lung	Blastomycin	Three years free of disease
[illegible] 1954		60	WM	Carcinoma	Left lung	None	Generalized dissemination, died 6 days postop
[illegible] 1954		50	WF	Chronic suppuration	Right lower lobe	None	Died 18 hours postop in status asthmaticus
[illegible] 1954		60	NF	Carcinoma	Left lung	None	Well 11 months postop
[illegible] 1954		41	NM	Chronic suppuration	Right middle lobe	Stilbamidine	Suspected spread in right lung. Well 10 months later
[illegible] DeCamp Ochsner							
Case 1	[illegible]	39	WF	Undetermined	Left lung	Blastomycin	Left 7th rib involved, thoracoplasty, died 2½ years later of cardiac arrest during rhizotomy
Case 2	C. D.	62	WM	Carcinoma, no treatment	Right lung	Blastomycin KI	Questionable bronchial stump disease 5 yr 9 mo free of disease
Case 3	F. R. L.	38	WF	Pulmonary cyst, no treatment	Left upper lobe	Blastomycin	5½ years free of disease
Case 4	E. S.	55	WF	Undetermined, no treatment	Right upper lobe	None	Died of coronary occlusion 7 months after surgery
Case 5	R. W. J.	37	WF	Undetermined, no treatment	Left upper lobe	None	Died in immediate postop period, pheochromocytoma found at autopsy
Case 6	C. McC.	41	NM	Blastomycosis 2-hydroxystilbamidine	Left lower lobe	2-hydroxystilbamidine	Eight months free of disease

* Personal communication from author

had an endobronchial mass. We have seen one case with a 3 mm. endobronchial mass, but none of our operative cases had significant endobronchial lesions.

Sputum.—Smear and culture of the sputum is the ideal way of making a positive diagnosis. Unstained pus particles from the sputum liquefied by potassium hydroxide, frequently reveal typical organisms. Diagnostic techniques are neither difficult nor costly,[22] but the organisms may be difficult to identify.

A positive skin test is considered significant when present, and the complement fixation test may become positive in extensive forms of the disease.[2, 3] Others consider the skin test to be of little value.[14, 24, 2]

TABLE III. DIAGNOSTIC FINDINGS IN 6 CASES OF PULMONARY BLASTOMYCOSIS TREATED BY RESECTION

CASE	X-RAY	BRONCHOSCOPY	SPUTUM CULTURE FOR FUNGI	PREOPERATIVE DIAGNOSIS
1. J. T.	Density, left apex (inflammatory)	Negative	Negative	Inflammatory disease
2. C. D.	Tumor, left upper lobe	Negative	Negative	Carcinoma
3. J. R. T.	Cyst, left upper lobe	Negative	Negative	Cystic disease
4. J. S.	Density, right upper lobe	Negative	Negative	Inflammatory disease
5. R. J.	Tumor, left upper lobe	Negative	Negative	Carcinoma
6. C. McC.	Cavity, left lower lobe	Negative	Positive for blastomycosis	Blastomycosis

We have established the diagnosis in a case of acute lung abscess by needle aspiration. Such a technique is rarely indicated. Diagnostic thoracotomy will continue to be necessary in some cases of localized, possibly neoplastic disease, but it is to be hoped that with increasing experience the diagnosis may be established more frequently without operation. In the 20 reported cases of pulmonary resection (Table II) the diagnosis was established prior to operation in only 4 instances. We made a preoperative diagnosis in only 1 of our 6 cases (Table III).

MEDICAL TREATMENT

Cutaneous blastomycosis has responded readily to treatment, whereas systemic lesions have not until recently responded regularly to any of a host of agents including the modern antibiotics. Martin[23] and Smith[1] report benefit from vaccine therapy either alone or followed by iodides. Weisel and Landis[24] are unique in reporting a small series of systemic cases successfully treated by oral and aerosolized iodide therapy.

In 1945 Elson[7] demonstrated the in vitro effectiveness of propamidine against certain fungi including *Blastomyces dermatitidis*. Stilbamidine (4,4′-stilbenedicarboxamidine) proved to be a more effective diamidine, and in 1951 Schoenbach and his colleagues reported the successful treatment of a case of systemic blastomycosis with this agent. A number of subsequent re ports have indicated that stilbamidine is a very effective agent in controlling blastomycosis[illegible] As yet however no large series has been reported and the follow up periods have been short

Stilbamidine is a relatively toxic agent[illegible] Breakdown products capable of damaging the liver and kidneys develop on exposure to ultraviolet light so that it is imperative that solutions be freshly prepared[illegible] The agent is contraindicated in cases of hepatic or renal disease A number of symptoms may accompany or shortly follow the administration of the drug intravenously hypotension tachycardia dizziness salivation syncope incontinence and the like A very annoying but rarely serious complication is the appearance several months after therapy of a fifth cranial neuropathy manifested by paresthesia hypalgesia and anesthesia over the region supplied by the trigeminal nerve

Equally effective against blastomycosis is 2 hydroxystilbamidine It is more stable in solution and is free of toxic reactions[13, 14, 23] Snapper and McVay[3] first reported satisfactory response to therapy in 4 cases with severe disease Large doses of the drug were given over long periods without the appearance of any toxic reaction other than a transient circulatory collapse on one occasion with the very rapid injection of the drug

As more experience accumulates it is apparent that these drugs are truly effective agents in blastomycosis but they will not in all instances control the disease Smith [illegible] has completed treatment with stilbamidine or 2-hydroxystilbamidine in 10 cases and 6 cases are now under therapy or have just completed treatment His results have been satisfactory Seabury[14] has treated 12 cases of systemic blastomycosis with these drugs No serious reactions occurred with 2 hydroxystilbamidine Seven cases have been treated long enough to be considered well controlled several as long as two years Three are now under therapy and are doing well In two cases treatment failed and [illegible] fourth case [illegible] resection of a residual destroyed lobe was necessary [illegible] failure occurred in a male with a thirty year history of disease He died [illegible] two weeks after admission The second failure was Case I M who had a destroyed right upper lobe two large cavities in the apex of the right [illegible] lobe and multiple cavities in the upper and lower lobes of the left lung Sputum conversion occurred under treatment but she relapsed three months after discontinuance of 2 hydroxystilbamidine and the organisms demonstrated resistance Murphy [illegible] has experienced good results in 2 cases but he [illegible] 2 failures

Patients are placed on a low protein low purine diet during treatment [illegible] the action of the drugs The agents are [illegible] prepared solutions as a slow intravenous drip Increasing [illegible] given up to 0.225 Gm in an adult The [illegible] Treatment may be continuous or in [illegible] 5 to 8 Gm for moderately extensive [illegible] cases with large [illegible] of necrosis or abscess formation. The drugs are stored for as long as a year in numerous tissues in the body and it is possible that the therapeutic effect is prolonged.

Longer follow-up periods and more experience will be needed to evaluate the effectiveness of treatment and to determine the best treatment regimens. Experience to date is sufficient to indicate their use in any visceral or serious cutaneous form of the disease. Unfortunately the drugs are expensive. Stilbamidine isethionate* has been available on prescription for some time. 2-hydroxystilbamidine isethionate* is now being released for general use.

SURGICAL TREATMENT

Pulmonary blastomycosis usually occurs as a diffuse lesion not amenable to surgical therapy but sometimes the lesion is localized and excisional therapy has appeared rational. We have been able to collect 20 reported cases of pulmonary resection for blastomycosis (Table II). Two of Smith's[1] cases, J. T. and C. D., are excluded from the reported series as they are included in our personal series. The bulk of the surgical experience with pulmonary blastomycosis antedates effective chemotherapy. In the majority of cases no effective fungistatic agent was available even after operation.

No follow-up is available in 2 cases and 3 patients died in the immediate postoperative period. Four cases died of dissemination of the disease from six days to two years after resection. Five patients developed signs of active disease following surgery but responded to medical treatment and the disease was arrested. This treatment included human serum, blastomycin, iodides, undecylenic acid, stilbamidine, and 2-hydroxystilbamidine. In 7 cases the disease was apparently controlled by pulmonary resection alone although blastomycin was used in one case. Murphy[7] reports a postoperative recurrence following lobectomy which has not responded to vigorous treatment with iodides, undecylenic acid, and stilbamidine.

Our experience with pulmonary resection in 6 cases of blastomycosis is briefly outlined.

CASE 1.—J. T., a 39-year-old white housewife from Tennessee, was admitted Aug. 10, 1947, with pain in the left anterior chest, fatigue, weakness, a daily fever of 102° F., and an 11 pound weight loss during the previous eight weeks. No cough or hemoptysis had occurred. On examination fine rales and decreased breath sounds were noted in the left apex. A therapeutic pneumothorax had been induced two weeks prior to admission. Laboratory studies were not remarkable. Sputum smears and cultures were repeatedly negative for tubercle bacilli and pathogenic fungi. A roentgen film exhibited a homogeneous density in the medial portion of the left apex. These changes had been absent in a film taken six months before. Unfortunately the films were lost. Bronchoscopic examination was negative. On Sept. 4, 1947, a left pneumonectomy was performed for a lesion in the left upper lobe, very firmly adherent to the parietal pleura, which was thought to be a carcinoma. Numerous organisms resembling *Blastomyces dermatitidis* were observed on tissue examination. Organisms were later cultured from a chest wall [illegible]. The skin test and complement fixation test were negative. Iodide therapy was [illegible]. Two weeks following operation a [illegible] lesion [illegible] the left [illegible] was [illegible] and the area irradiated with [illegible]. [illegible] and skin [illegible] appeared the following year. [illegible] for severe intercostal neuralgia. A second costectomy was performed elsewhere. On June [illegible] 1950 while undergoing a posterior rhizotomy for persistent pain she developed cardiac [illegible] and died.

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*The William S. Merrell [illegible]

Comment.—Surgical therapy failed in this case because of systemic spread of the disease which occurred concurrently with operation.

Case 2.—C. D., a [illegible] year old white businessman from Alabama, was admitted June [illegible] 1948, complaining of cough, hemoptysis, afternoon temperature of 102° F, easy fatigue and a [illegible] pound weight loss. Physical examination revealed râles and dullness posteriorly and laterally in the right lower chest. The sedimentation rate was elevated. The hemogram was not remarkable. Sputum examinations were repeatedly negative for all pathogenic fungi. Roentgenographs revealed a shadow in the dorsal segment of the right lower lobe suggesting an abscess associated with tumor (Fig. 1 A). Bronchoscopy was negative. Skin test and complement fixation studies were negative postoperatively. On June [illegible] 1948 a right pneumonectomy was performed for a suspected carcinoma. Smear, tissue section and cultures all demonstrated *Blastomyces dermatitidis*. Occasional hemoptysis

Fig. 1 (Case 2).—C. D. [illegible] roentgenogram; *B*, roentgenogram seventeen months after right pneumonectomy.

Bronchoscopy was negative. On this admission, surgery was performed for an unrelated condition. She was readmitted on Jan. 22, 1948, complaining of blood-streaked sputum, frank hemoptysis of [illegible] ounces of blood on two occasions six weeks apart. There were no

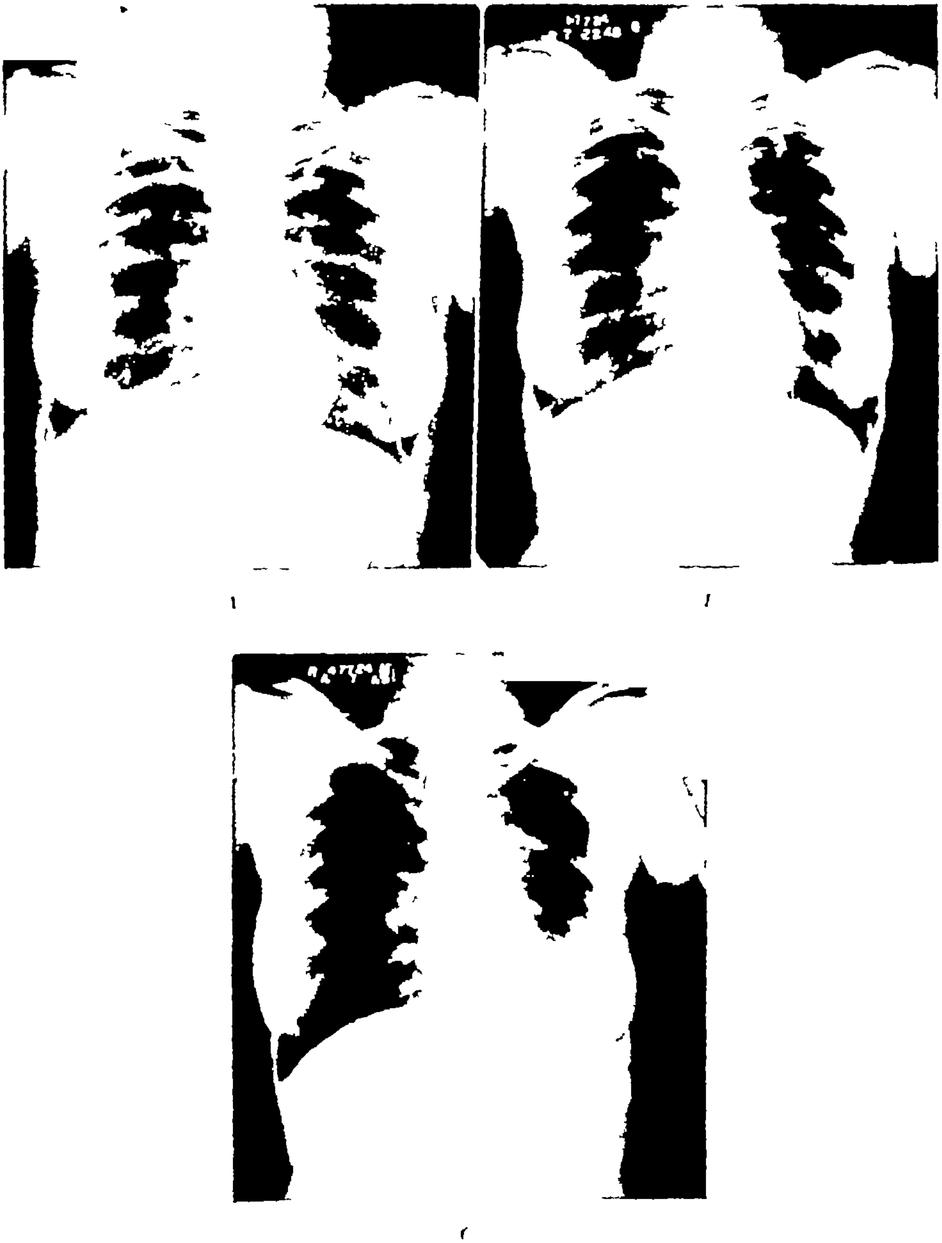
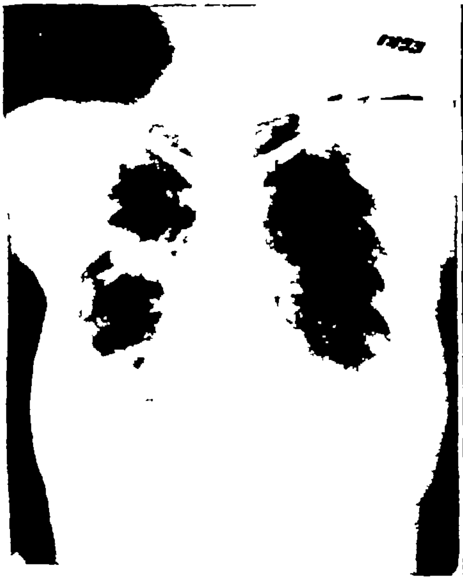


Fig. 2.—Case [illegible], J. I. T. A, Roentgenogram, June [illegible]. B, Roentgenogram, January 1948. C, Roentgenogram eight months following left upper lobectomy.

other symptoms. Physical findings were not remarkable. Roentgenography revealed a thin-walled air cavity in the left apex [illegible] the size of the cavity seen two years previously (Fig. 2, B). The [illegible] repeated sputum studies were negative for [illegible] mycosis On Aug 2, 1948, a left upper lobectomy was performed The upper lobe was densely adherent to the parietal pleura and it contained a 1 5 by 2 0 cm cavity Smear tissue sections, and culture revealed *Blastomyces dermatitidis* Iodides were given em



A

B

C

Comment.—A persistent cavitary lesion due to blastomycosis was apparently cured by lobectomy.

CASE 4.—F. S., a 55-year-old white housewife from Mississippi, was admitted on June 6, 1952, with a three months' history of chills, fever to 101° F., daily cough, and malaise. The patient also had angina pectoris and required as many as 100 nitroglycerin tablets per week. Physical examination was not revealing. Roentgenography revealed an irregular shadow adjacent to the right hilum and located in the anterior portion of the right upper lobe (Fig. 3, A and B). Bronchoscopy was negative. Sputum smears were negative for fungi and cultures were later reported as negative. Hemogram was normal. The electrocardiogram showed definite evidence of myocardial disease. On June 13, 1952, a right upper lobectomy was performed for a hard granulomatous lesion. Tissue section and cultures of hilar lymph nodes were positive for *Blastomyces dermatitidis*. The postoperative course was uneventful and the patient appeared to be free of pulmonary disease (Fig. 3, C). She died suddenly at home five months later of coronary thrombosis.

Comment.—The blastomycosis appeared to be controlled in this case until the time of her death from a myocardial infarction.

CASE 5.—E. W. T., a 37-year-old white housewife from Mississippi, admitted Aug. 20, 1952, with cough, hemoptysis, low-grade fever, malaise, left anterior chest pain, and a 24 pound weight loss during a two-month period. She had experienced attacks of dyspnea and palpitation without hypertension occurring at one- to two-month intervals for three years. Roentgenography revealed a large circumscribed lesion in the anterior segment of the left upper lobe (Fig. 4, A and B). The hemogram was normal. Sputum smear and

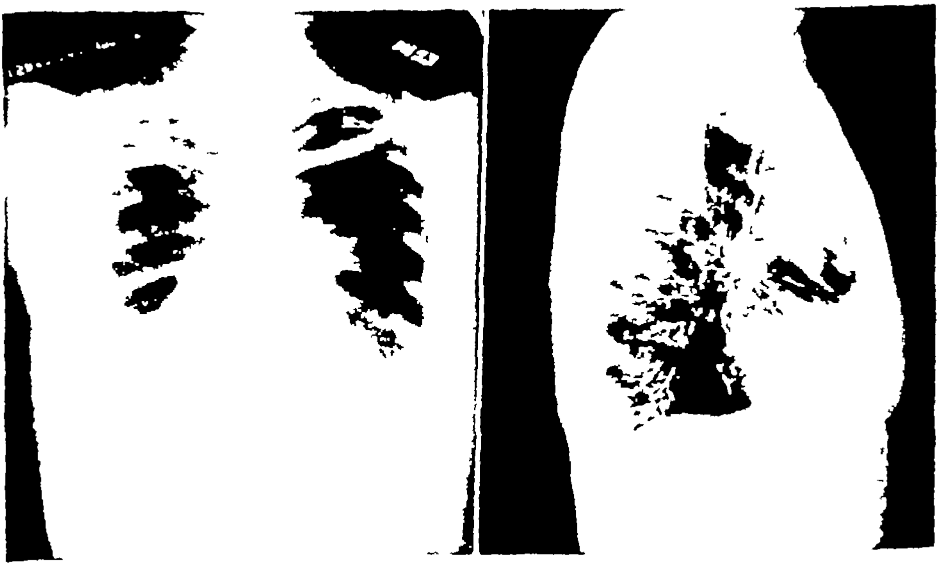
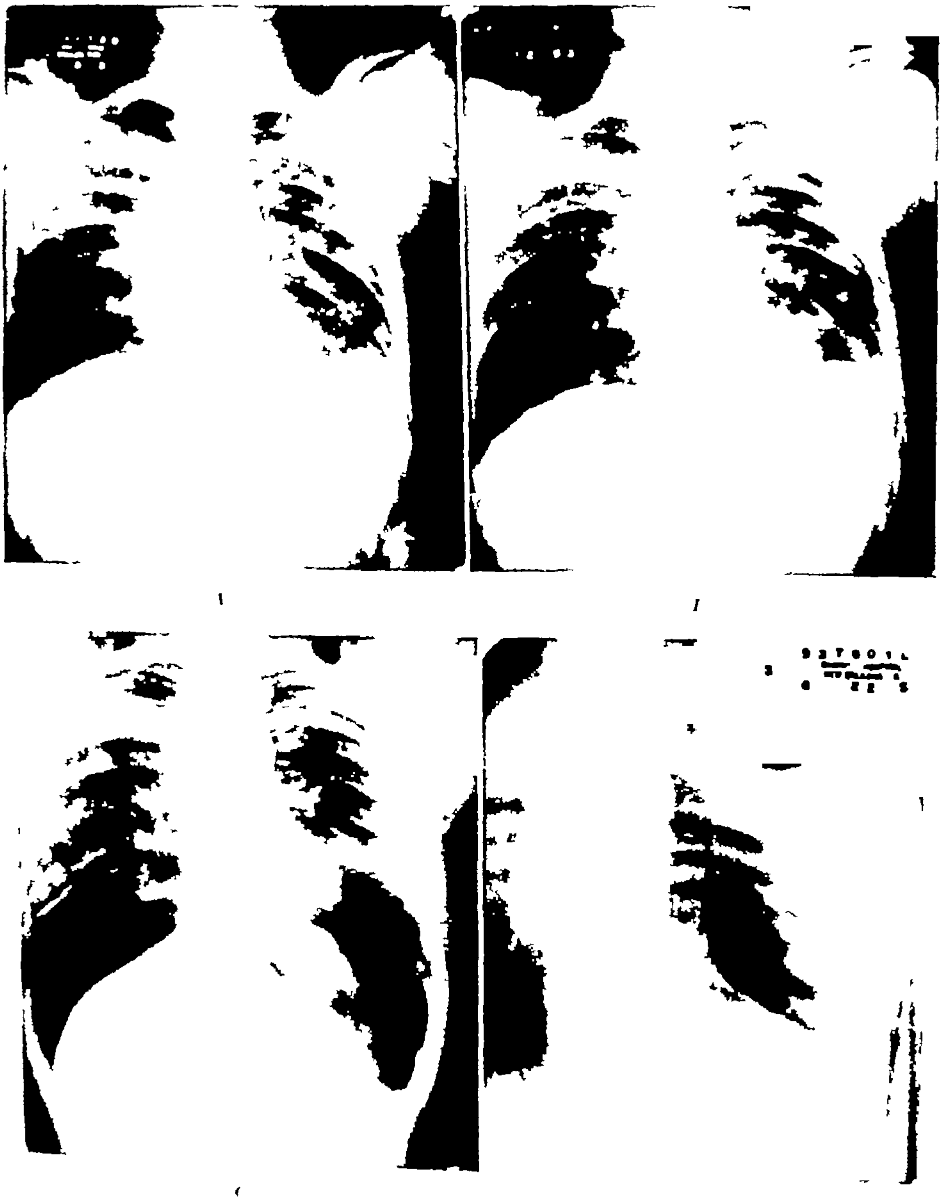


FIG. 4.—Case 5, E. W. T. A and B, Roentgenograms showing circumscribed lesion in anterior segment of left upper lobe.

culture results were negative for fungi. A bronchoscopy was negative. On bronchography the left upper lobe bronchus [illegible] filled with dye (Fig. 4, B). On Aug. 2[illegible] a left upper lobe [illegible] a 5 cm. granuloma in the ant[illegible] [illegible] The patient [illegible] [illegible] operating table [illegible] [illegible] from [illegible] following operation [illegible] [illegible]

Comment—This is a most regrettable fatality due to an unsuspected pheochromocytoma

Case 6—C. McC., a 41 year old Negro laborer from Louisiana, was admitted to the Charity Hospital on March 28, 1952 with a history of onset of cough and high fever ten

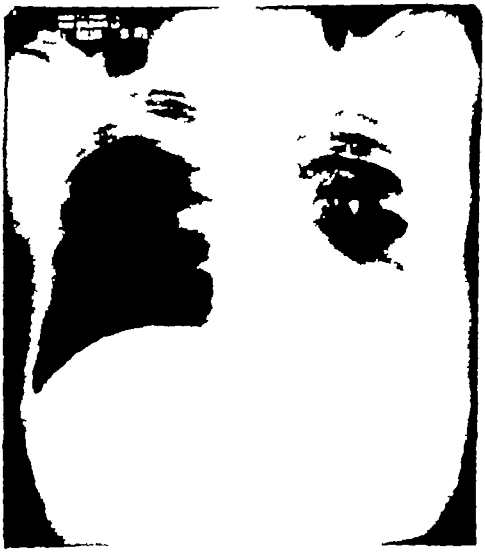


[illegible]

indurated ulcer of the left cheek appeared and persisted. Biopsy of the ulcer revealed *Blastomyces dermatitidis* on tissue section and on culture. The patient was almost totally blind from cataracts. On physical examination a 3 cm. shallow ulcer was present on the left cheek. Moist râles were present over both lung fields. Routine laboratory studies were normal. Roentgenography revealed bilateral infiltration involving principally the upper half of the lung fields, patchy but firm in appearance (Fig. 5, *A*). The apices were *not involved. The sputum was repeatedly positive on smear and culture for blastomycetes.*

Medical treatment was directed by Dr. John Seabury. On April 11, 1953, he was started on 250 mg. of 2-hydroxystilbamidine intravenously daily for three days and then every other day until May 8, 1953 (Fig. 5, *B*). A total of 3.75 Gm. was given. The ulcer of the cheek healed rapidly. Pneumoperitoneum was commenced in an effort to collapse cavities in the right mid lung and the left lower lobe. A second course of 3.75 Gm. of the drug was commenced on May 24, 1953, with 15 doses of 250 mg. given intravenously every other day (Fig. 5, *C*). By Aug. 22, 1953, the right lung and the left upper lobe had cleared considerably but the left lower lobe became progressively atelectatic and planograms demonstrated honeycombing and one large area of cavitation (Fig. 5, *D*). A severe hacking cough persisted.

The patient received a third course of 2-hydroxystilbamidine, 225 mg. daily for seven days prior to operation and for five days postoperatively. On Sept. 18, 1953, a left lower lobectomy was performed. Because of dense adhesions the resection was technically very difficult. The lobe was almost completely replaced by fibrous tissue and contained one large multiloculated cavity measuring 5 by 4 cm. No culture was made of the lung. Since operation the patient has been free of all symptoms referable to blastomycosis and sputum cultures have been repeatedly negative for blastomycetes (Fig. 5, *E*).



E

Fig. 5, *E*.—[illegible] 195[illegible], two months after left lower lobectomy and total of [illegible] of 2-hydroxystilbamidine.

Comment.—The management of this case [illegible] approaches the ideal. The diagnosis was established and vigorous specific therapy was administered. In spite of extensive bilateral disease, symptomatic improvement and clearing of the roentgen shadows occurred but with evidence of residual complete destruction and cavitation of the left lower lobe. [illegible] relieved the patient of his residual [illegible]

In summary, we have performed 2 pneumonectomies and 4 lobectomies for pulmonary blastomycosis. The diagnosis was established prior to operation in only 1 case. In 2 cases bronchogenic carcinoma was suspected, in 2 cases an inflammatory lesion, and in 1 case a persistent cavity of undetermined etiology was present. Three patients died: one immediately following surgery from a sustained tachycardia incident to a pheochromocytoma; a second three years after resection during an operation to relieve pain incident to her recurrent disease. The third patient, apparently free of blastomycosis, died of a myocardial infarction six months after operation. Three patients are alive and well 9 months, [illegible] months, and 60 months, respectively, after resection. This last patient may have had postoperative activity of his disease the first year after operation.

DISCUSSION

It seems inescapable that the diagnosis of blastomycosis is frequently missed both clinically and at autopsy. The organisms are difficult to recognize in exudates and in tissues and the pathologic lesions are not diagnostic. Whenever diagnostic suspicion has increased, the incidence of the disease in the locality has arisen. It is quite likely that a number of self-limited unrecognized cases have occurred. It is our experience that even when the disease is suspected, diagnosis is sometimes difficult and we have failed to recover organisms on repeated examination and culture of sputum in cases with active disease.

The best chemotherapeutic agent known is 2-hydroxystilbamidine because of its effectiveness and freedom from toxicity. It will usually but not always cause a regression of the pathologic lesions with closure of cavities.[14] It will usually cause the sputum to revert to negative and will alleviate the clinical manifestations of the disease.

Blastomycosis, contrary to many published pathologic studies, may cause extensive destruction of pulmonary tissue with abscess and cavity formation. It is to be expected, as several authors have suggested,[17, 25, 31] [illegible] that in some instances surgical excision of residual cavities and destroyed tissues will be indicated following chemotherapy. Certainly such was true in our Case 6 and would probably have been true of the cavitary lesion in our Case 3. Only further experience will indicate how frequently planned surgical excision will be necessary following chemotherapy.

Smith has had no occasion to recommend excision in his experience with 16 cases. Our Case 6 represents one indication for resection in 12 cases treated by Seabury. In some cases recently under treatment it is too early to decide whether resection will be indicated. In his case L. M. lung destruction was so general that resection was out of the question. Hughes[19] has two cases under observation following stilbamidine therapy which he feels should appropriately have the residual lesions resected.

The parallelism between the management of pulmonary tuberculosis and pulmonary blastomycosis is apparent. Both represent phases of a systemic infection. Effective chemotherapy is available for both. In both conditions [illegible] excision is helpful in the removal of destroyed tissue and residual [illegible] remaining after treatment.

It is highly desirable that the diagnosis be made prior to operation. With [illegible] chemotherapy operation may be obviated, but if required will be much safer. Diagnostic thoracotomy may still be occasionally required, and if the diagnosis is made only after resection a postoperative course of 2-hydroxystilbamidine is indicated. The amount of drug that should be used depends on the character of the lesions present. If resection is impossible, diagnostic biopsy is valuable as it will enable specific chemotherapy. Resection may be possible later if required.

CONCLUSIONS

1. Pulmonary blastomycosis is not uncommon in some localities in North America. An increased incidence of the disease commonly follows greater clinical suspicion coupled with vigorous diagnostic efforts.

2. On the basis of three years' experience 2-hydroxystilbamidine appears to be an effective, nontoxic therapeutic agent for blastomycosis.

3. In some cases of pulmonary blastomycosis lung resection is required following control of the active disease by diamidine therapy. One such case is reported.

4. Pulmonary resection or biopsy, in unsuspected cases of pulmonary blastomycosis is hazardous and should be promptly followed by vigorous diamidine therapy. Every effort should be made to establish the correct diagnosis and to administer 2-hydroxystilbamidine prior to operation.

5. On the basis of relatively short term observations the prognosis of pulmonary blastomycosis is excellent when treated with 2-hydroxystilbamidine followed by surgical resection if necessary.

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DISCUSSION

DR. M. M. NEWMAN (St. Albans, N. Y.).—We have had the opportunity of treating [illegible] at St. Albans in collaboration with Dr. I. Snapper [illegible]

[illegible] tion of a granuloma [illegible] followed by [illegible] and decortica[illegible] He had fever, anorexia and [illegible] hospital [illegible]

(Slide.) He received supportive care after which another decortication of the right lung was done on June 16, 1952. About three weeks after operation he developed headache and fever. Lumbar puncture showed turbid fluid from which *C. immitis* could be cultured. He was transferred to Mt. Sinai Hospital. There he received 23 Gm. of 2-hydroxystilbamidine from July 28, 1952, to Nov. 5, 1952. There was complete disappearance of meningeal signs. He gained 70 pounds and had no residual neurologic disability. This man now drives a large tank truck between cities in northern New York.

(Slide.) This was a 28-year-old white male who was stationed at an Air Force base in Arizona. Between August, 1950, and August, 1952, he had five spontaneous pneumothoraces. In July, 1952, he had a right spontaneous pneumothorax. The lung failed to re-expand on suction and a cavity was seen in the right upper lobe. PPD No. 1 was positive, coccidioidin No. 2 was doubtful. In October decortication of the right lung and resection of the posterior segment of the right upper lobe was done under the impression that this was tuberculosis. Postoperatively there was a fistula and empyema. In December he had a second decortication and culture of the specimen showed *Coccidioides immitis*.

(Slide.) The lung collapsed again. Coccidioidin skin test had become strongly positive; complement fixation was positive at 1:80. A nine-rib thoracoplasty was done to control the empyema. Between December, 1952, and August, 1953, he received 8 Gm. of 2-hydroxystilbamidine with no apparent change. Between August and October, 1953, he received another 8 Gm. Three of six gastric cultures in November, 1953, were positive for *C. immitis*. In December he received a new drug, 2-aminostilbamidine, and since then has had seven consecutive negative cultures.

We feel we are in a new era in treatment of the deep mycoses.

DR. FELIX A. HUGHES, JR., Memphis, Tenn.—Stilbamidine and 2-hydroxystilbamidine have been used for blastomycosis at Kennedy Hospital by Dr. Sutliff, Chief of the Infectious Diseases Section. In April of this year, Dr. Sutliff, Dr. Kyle, and Dr. Hobson reported the results of the treatment of 25 cases of blastomycosis in Memphis to the American College of Physicians and Dr. Sutliff kindly allowed me to review the paper and some of my remarks are based on this paper. Seventeen of these cases were at Kennedy, eight were at other hospitals in Memphis. The mortality in these cases has been 8 per cent with a total mortality of 20 per cent. Eight per cent is in contrast to 35 per cent in the series of Smith and associates and 78 per cent in the series of Martin and co-workers.

The prognosis apparently has been greatly improved. Before the advent of the aromatic diamidines 11 cases were treated; 5 of these were arrested, 3 by surgery—2 by pulmonary resection and 1 by excision of a skin lesion. These surgical excisions gave the only immediate cures in this group. Stilbamidine was used in the treatment of 7 cases; one of these has a persistent pulmonary lesion that apparently should be resected. In 12 cases 2-hydroxystilbamidine was used with *7 arrested but 2 have persistent pulmonary* lesion. In all 3 cases have persistent pulmonary lesions that we think should probably be removed. At the present time our inclination would be to give hydroxystilbamidine to the known cases of blastomycosis with a solitary pulmonary lesion as the initial treatment. These cases could then be followed by planograms and cultures so that an active and/or persistent pulmonary lesion could be removed.

There are other reasons to indicate that surgery might be useful. One is the unpredictability of this disease in that it tends to recur after being apparently cured. The other is that in the two cases we have [illegible] without the use of the drug the patients have remained well.

DR. O. THERON CLAGETT, Rochester, Minn.—I suspect very strongly that blastomycosis is [illegible] as pulmonary histoplasmosis and coccidioidomycosis [illegible] I think the [illegible] in many respects. It is time to recognize the [illegible] mild pulmonary [illegible] spontaneously [illegible] commonly. However, [illegible] that I want to [illegible] has been present [illegible] the [illegible] of the disease that tells [illegible]

[illegible] of blastomycosis represents but I do think we have to recognize that there is a [illegible] natural tendency for blastomycosis to heal spontaneously and that an accurate [illegible] of the efficacy of stilbamidine in the treatment of blastomycosis will require [illegible] experience

[illegible] Dr Kunkel Dr Weed Dr McDonald and I reviewed 90 cases of blastomycosis that have been seen at the Mayo Clinic In 54 the lesion was primarily cutaneous [illegible] systemic Of the 36 systemic infections 10 were treated by surgery and [illegible] healing occurred even though the infection involved lung bones neurologic [illegible] genito-urinary system In our experience the treatment of blastomycosis with stilbamidine has not been uniformly successful Our surgical experience with pulmonary blastomycosis [illegible] of six patients in whom pulmonary resection was carried out All [illegible] alive four of them are well one developed blastomycosis of the contralateral chest wall [illegible] to the pulmonary resection As an indication of the chronicity of blastomycosis and the difficulty in knowing when it is actually healed one case in our experience had cutaneous blastomycosis thirty two years previous to pulmonary resection for pulmonary blastomycosis

DR WILL C SEALY Durham N C—We have had an extensive experience with blastomycosis at Duke Hospital it seems that there are a great many cases in the *eastern* part of our [illegible] I would like to say one word about the diagnosis In our last 12 cases we have not done [illegible] because the diagnosis has been made clinically They have been treated with drugs and have not required operation The last three cases have been children and by [illegible] tracheal aspirations the organisms were demonstrated on smears The [illegible] is sometimes of considerable importance If it is positive with a [illegible] I think one should be more than suspicious of blastomycosis and [illegible] studies Of course if it is negative it does not rule out blastomycosis

The [illegible] neuropathy with treatment with stilbamidine occurs very frequently [illegible] months after treatment and it does not occur until the patient [illegible] sunlight We had one patient with blastomycosis of the *trachea* who developed neuropathy six months later The operation was done in the winter and he was [illegible] until summer and then developed trigeminal neuropathy Our [illegible] in treating tic douloureux I might say this complication [illegible] hydroxystilbamidine for in one patient with extensive coccidioidomycosis treated [illegible] development of trigeminal neuropathy just as with stilbamidine [illegible] report of less of toxicity may be due to the fact th[illegible] ultraviolet radiation

DR [illegible] I would like to thank our discussers very much We recog[illegible] drugs have come forward and we are [illegible] going to happen in time We [illegible] preoperative diagnosis extremely difficult to make [illegible] of blastomycosis has been [illegible] treatment with 2 hydroxystilbamidine [illegible] great

THORACOPLASTY

A New Osteoplastic Technique

Viking Olov Bjork, M.D.
Stockholm, Sweden

PARTIAL thoracoplasty with extrafascial apicolysis according to Semb[1] has proved to be a valuable procedure which we will continue to use in selected cases. After a personal experience of more than 300 first stage operations according to Semb, a new technique has gradually been developed in order to overcome the disadvantages inherent in rib resection with apicolysis.

These disadvantages encountered are:

1. In the immediate postoperative period the unstable chest wall after the rib resection will considerably alter the normal physiology of respiration.[2]
   - A. The paradoxical movements of the lung will impair the alveolar ventilation.
   - B. *The unstable chest wall will impair an effective cough mechanism* and increase the incidence of atelectasis.
   - C. Accumulation of fluid in the apicolysis space may produce a considerable compression atelectasis of the lung. In the atelectatic part of the lung the blood will pass nonventilated alveoli and return unsaturated to the left atrium. A decreased arterial oxygen tension will result for a period of several weeks.[3]
2. During the first year after the operation there is some re-expansion of the lung which in many cases will result in the reopening of a cavity.

Attempts to overcome these disadvantages have been made along the following lines:

I. The apicolysis space has been *filled with plastic material.* This has then to be removed after some weeks at a second stage or it is left in place. The plastic plomb may, however, become infected after some months or years. If then a bronchial fistula is found, extensive resection of the chest wall and lung tissue has to be done.

II. Holst has described several improvements.[4] The ribs are divided anteriorly and posteriorly and sutured down under a rib, usually the fifth

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From Sabbatsberg Hospital, Surgeon in chief C. Crafoord, M.D. [illegible] Hospital [illegible] M.D. [illegible] Hospital [illegible]

This work has been aided by the Swedish National Association Against Tuberculosis.

[illegible]

left in place but stripped from the periosteum. The first rib was left intact and an extrapleural apicolysis was performed. A fixation of the apical pleura was performed. A thin pleura, however, is considered a contraindication to this procedure.

III. Extrapleural air refills have been performed but not found worth while. The apex of the lung is found on approximately the same level whether air refills have been given or not.

THE AUTHOR'S TECHNIQUE

General Principles.—

A new roof of the thorax is obtained by resection of posterior portions of the ribs in increasing lengths from above and downward. The ribs are then bent in the costal cartilages and fixed to the posterior end of the uppermost intact rib by stainless steel sutures through drill holes. An extrapleural apicolysis to the aortic arch or the azygos vein is performed. The first rib is divided both anteriorly and posteriorly and fixed to the transverse process of the fifth or sixth rib. The first rib will then prevent the lung from re-expanding above the new dome. Thus the two disadvantages with modern thoracoplasty have been overcome:

1. A stable chest wall has been obtained.
2. The lung is prevented from re-expanding above the new roof.

When the thoracoplasty is used in combination with resection the first rib may be left in place. Then the second rib must be fixed as close to the mediastinum as possible. A repair of the mediastinal pleura to the first intercostal muscle bundle is also necessary. With this modification a stable chest is obtained. Even with a very thin pleura only a negligible re-expansion of the lung may be found.

Details of the Surgical Procedure.—

First Step. Incision.—A paravertebral incision is made and continued anteriorly at least 5 cm below the tip of the scapula. In a case where resection and thoracoplasty is performed the incision is carried forward along the lower border of the fifth or sixth rib. The paravertebral part of incision is placed about [illegible] cm from the midline. The posterior flap is undercut as far [illegible] to permit division of the trapezius and the rhomboid muscles as near as possible to the spinous processes.

Second Step. Elevation of Scapula and Preparation of Resection Area.—The [illegible] is exposed and the serratus posterior medius and anterior [illegible] insertion to the first and second rib are divided well [illegible] the periosteum to avoid impairment of the nutrition [illegible]

Third Step. Rib Resection.—The posterior ends of usually the upper [illegible] usually the upper seven are re- [illegible] used [illegible] thoracoplasty will be [illegible] of the transverse [illegible] little more than 5 [illegible] breadths of the fifth rib, 4 fingerbreadths of the fourth rib, 3 fingerbreadths of the third rib, 2 fingerbreadths of the second rib, and 1 fingerbreadth of the first rib are resected. Before the ribs are fixed they are bent down to the intended position to ascertain their optimal length and position. Sometimes more of the ribs, usually of the fifth and first, has to be resected. It is important to resect enough of the first rib to have it as straight as possible (Fig. 2) and fix it as close to the mediastinum as possible. Otherwise the lung may expand through the aperture medial to the first rib (Fig. 3). The periosteum is stripped away from the upper border of the posterior end of the sixth rib.

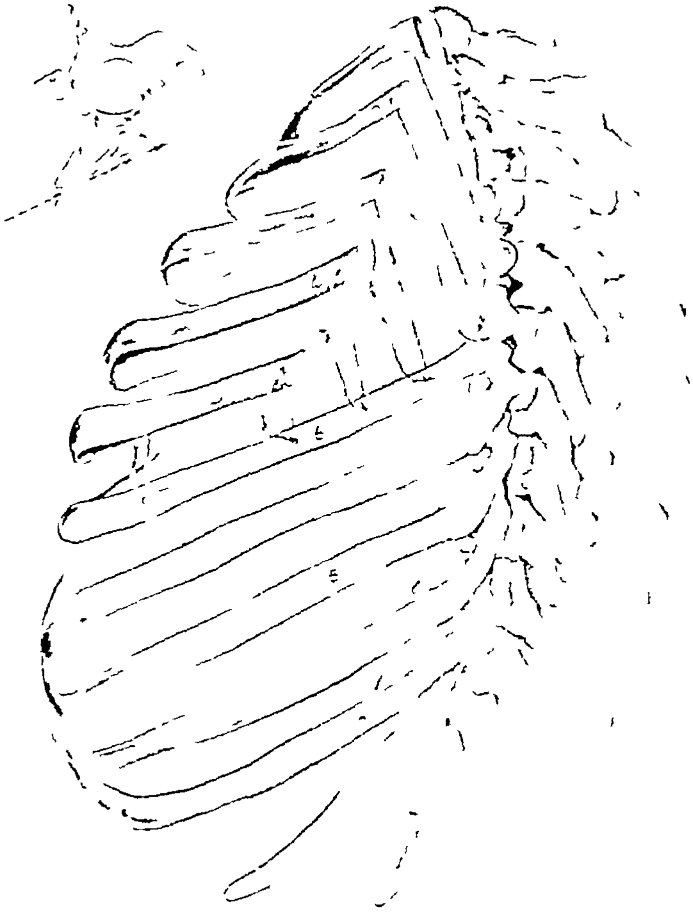


Fig. 1.—The posterior ends of the upper five ribs are resected in increasing lengths.

Fourth Step: Apicolysis.—The upper four intercostal bundles are divided. Then an extrapleural strip starts above the first rib. If the pleura is thin the apicolysis is performed in the extrafascial plane. The posterior cut end of the first rib is pulled downward with the Semb rib forceps, when remaining attachments of scalenus medius and anticus are cut with scissors (Fig 4) The subclavian vein is gently detached from the first rib and the posterior

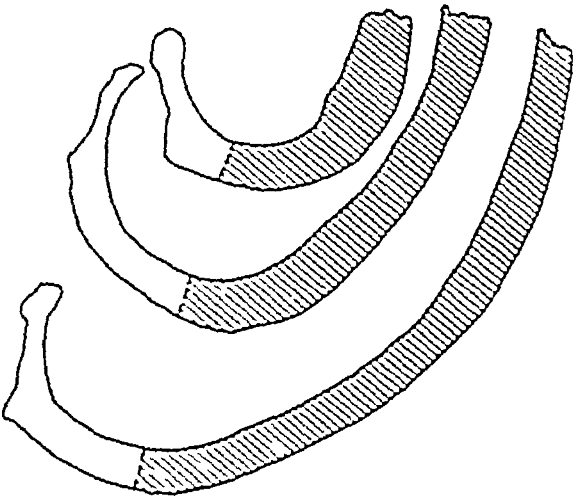


Fig 2

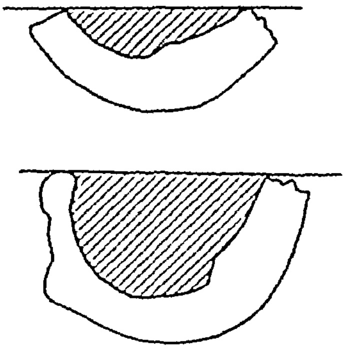


Fig 3

Fig 2 — [illegible] of the first and second rib must be resected in order to have the remaining portion of the rib as straight as possible

Fig 3 — If too short a segment of the first rib is resected there will be an aperture medial to the rib with herniation of the lung (lower diagram) When more of the first rib is resected it can be fixed close to the mediastinum (upper diagram)

[illegible]

aspect of the costoclavicular (rhomboid) ligament which is divided with scissors. The first rib may now be pulled more downward and outward when the medial aspect of the first costal cartilage anteriorly to the internal mammary artery is gently dissected avoiding damage to this artery and the pleura. The first costal cartilage is cut as close to the sternum as possible and the perichondrium is divided anteriorly. Now it is easy to bend the ribs downward and carry the apicolysis down to the aortic arch on the left side or to the azygos vein on the right side. If the pleura is inadvertently opened a tube is immediately inserted intrapleurally for continuous suction.

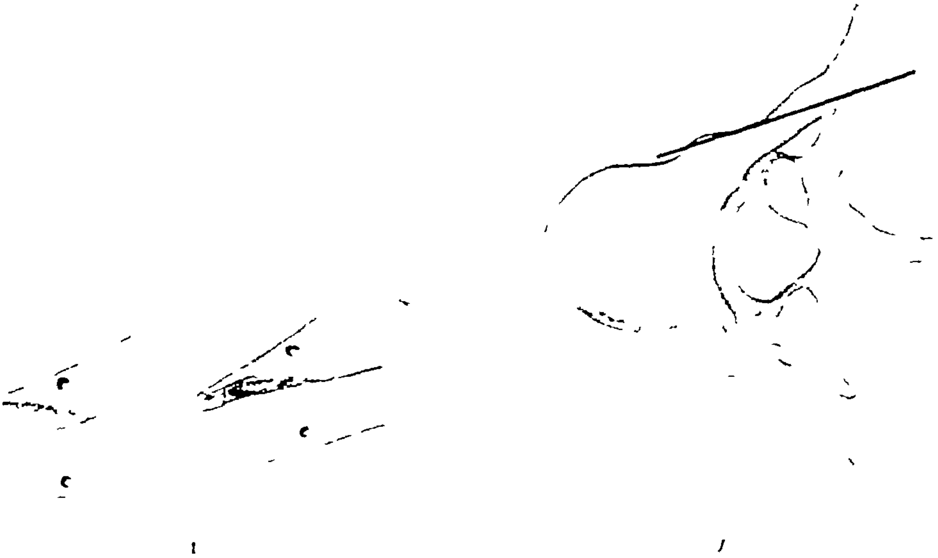
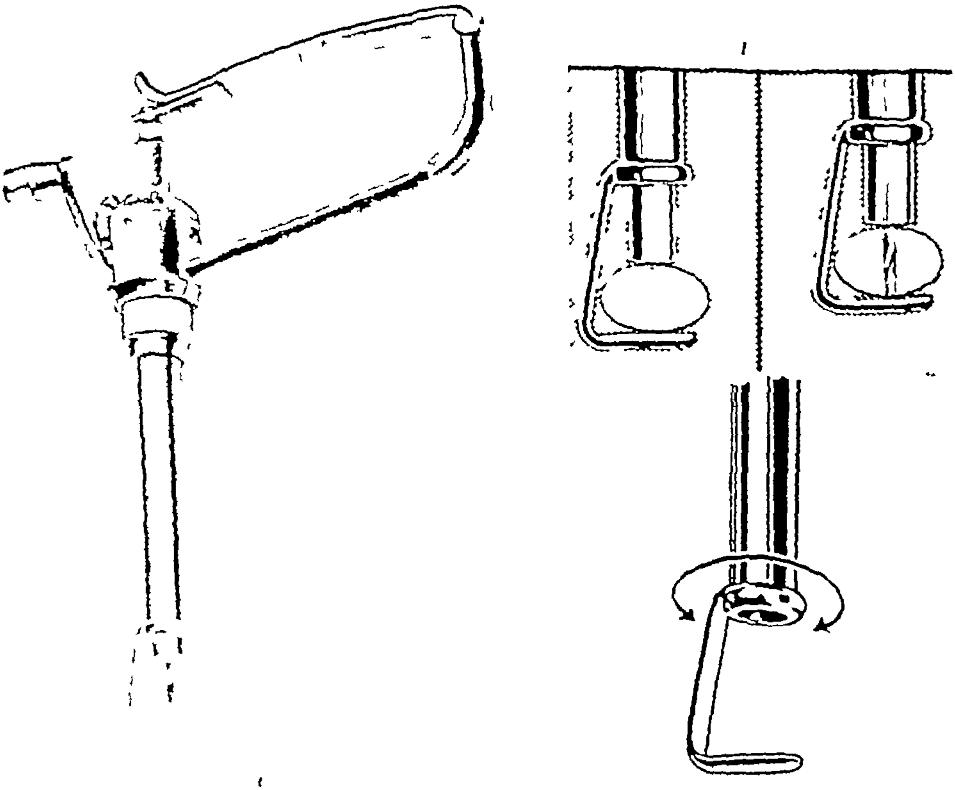


Fig. 5.—A. The holes are placed close to the upper border of the resected ribs and close to the lower border of the sixth rib. This will prevent the sutures from cutting through the ribs. B. For the first rib a hole is drilled through the transverse process and the remaining portion of the fifth or sixth rib.

Fifth Step. Fixation.—Small drill holes are made in the posterior ends of the divided ribs. These holes are placed *as close to the upper border of the rib as possible.* Corresponding holes are then made in the lower border of the sixth rib (Fig. 5, A). *This will prevent the sutures from cutting through the ribs.* For the second rib a hole is drilled in the sixth rib medial to the transverse process. *For the first rib a hole is drilled through the transverse process and the remaining portion of the fifth or sixth rib* (Fig. 5, *B*). In the most posterior holes an *ordinary* drill bore is used, a spoon being placed inside the chest to prevent injury to the lung. To make the other holes I use an especially designed drill bore (see Fig. 6) manufactured by Stille, Sweden, modified from Brock. Stainless steel sutures of 0.8 mm. diameter are threaded through the holes. If these are difficult to find a wide bore needle is passed through the hole and the steel thread inserted into the needle. Finer stainless steel sutures and wires have been found to break too easily. The ribs are then bent in the cartilages. The sutures are drawn taut and tied when a stable roof of the chest is obtained (Fig. 7). A fixation of the mediastinal pleura to the first rib is then performed (Fig. 8).

A drainage tube is always left in the apicolysis space and intermittently opened to drain off the accumulated fluid. As the roof of the chest is stable the accumulated fluid will not compress the lung as in an ordinary thoracoplasty, but instead the air in the apicolysis space is forced by the fluid into the tissues producing a subcutaneous emphysema. The tube is left in twenty-four to forty-eight hours only.



[illegible] radially [illegible] drill [illegible] [illegible] not [illegible] and the lung [illegible] [illegible] of the [illegible]

[illegible] Technique When the Thoracoplasty Is Used Simultaneously With [illegible]

[illegible] The thorax is opened after resection of [illegible] the [illegible] sixth rib. The periosteum is then stripped [illegible] the rib and the chest is entered through this [illegible] surrounded by [illegible]. After completion of the [illegible] steps to the [illegible]plasty are followed or [illegible]

[illegible] muscles [illegible] on the

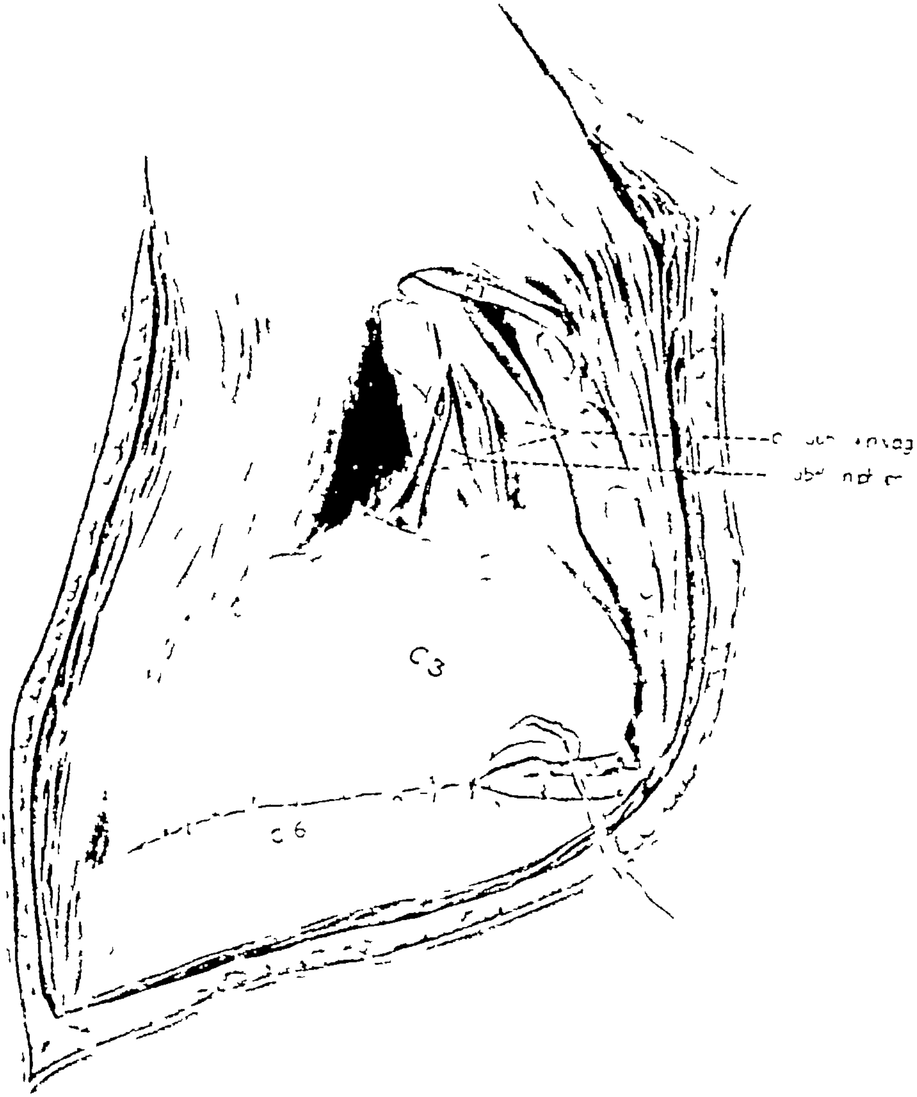


Fig. [illegible].—The ribs are bent in the cartilages. The sutures are drawn taut and tied when a stable roof of the chest is obtained. The apicolysis has been carried down to the aortic arch. (Left-sided thoracoplasty.)

Third Step.—The ribs are resected as above but the first rib is left in place. The periosteum is then stripped off its inside for its entire length.

Fourth Step.—The intercostal bundles are divided posteriorly. The extrapleural apicolysis is carried down to the hilum.

Fifth Step.—Luxation is accomplished as above. Special care is taken to resect enough of the second rib in order to make it as straight as possible.

(Fig. 3) The second rib is fixed as close to the mediastinum as possible by a stainless steel suture through a drill hole in the sixth rib medial to the tip of the transverse process. Before the steel sutures are tied a row of interrupted catgut sutures will approximate the two lower intercostal muscle bundles posteriorly into a cushion of muscles between the ribs and the lung (Fig 9)

Then a fixation of the mediastinal pleura is made in the following manner A piece of pleura close to the azygos vein on the right side and the aorta on the left side is elevated by a pair of forceps and ligated One end of the thread used for ligation is threaded on a needle which is passed through the periosteum of the first rib and the first intercostal bundle and then tied to the free end (Fig 8) A series of four to six sutures of this type will prevent expansion of the lung even if the pleura is thin provided the second rib is cut short and placed very close to the mediastinum

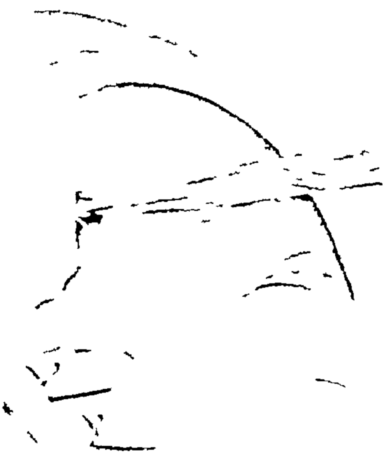


Fig. 8

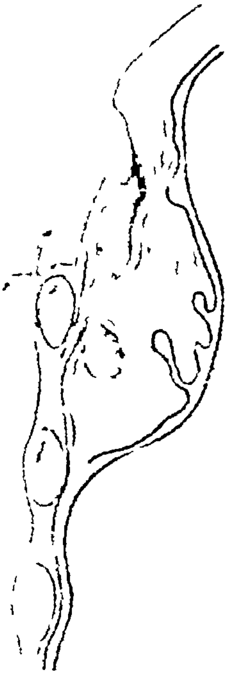


Fig. 9

[illegible] tinal pleura. A piece of pleura close to the azygos vein on [illegible] is elevated by a pair of forceps and ligated. On [illegible] which is passed through muscles left on the [illegible] Four to six such sutures will prevent expansion of the [illegible]

[illegible] suture will approximate the two lower intercostal [illegible] muscle bundles is formed between the lung and

After an extrapleural resection naturally no apicolysis can be performed [illegible] mediastinal pleura left. Instead the azygos vein on the right side [illegible] on the left are fixed to the first [illegible] roof. A careful fixation to the medi[illegible] some of the stainless steel [illegible]

Two drainage tubes are inserted intrapleurally and one in the apicolysis space for continuous suction during forty-eight to seventy-two hours.

THORACOPLASTY AS A PROCEDURE PER SE

Results.—The new type of thoracoplasty has been performed as a procedure per se or preliminary to a resection in 18 cases. In 14 cases a five-rib thoracoplasty and in 4 cases a six-rib thoracoplasty were performed. The first rib was always divided both anteriorly and posteriorly and left on the lung fixed as close to the mediastinum as possible.

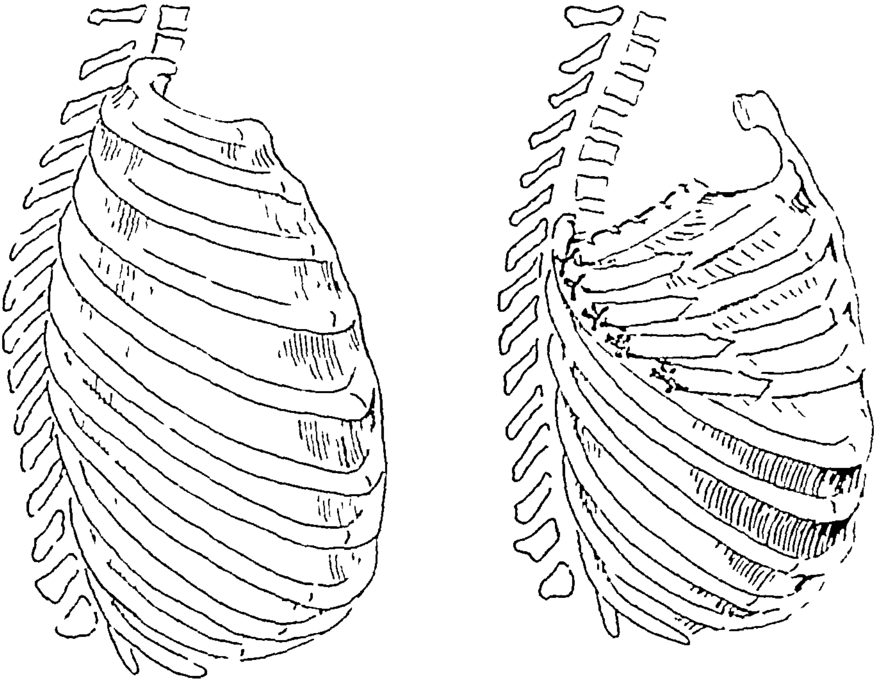


Fig. 1[illegible].—The ribs that were parallel have been brought to converge on the posterior part of the first rib.

The immediate postoperative course has been smooth in all cases. There has been infection of the apicolysis space in one case. There was no case with atelectasis. The cosmetic result has been good and there are no limitations in the movements of the scapula. As the divided ribs are fixed to the posterior part of the uppermost intact rib, a rounded roof of the chest is obtained and there is no possibility of the scapula's being fastened behind a rib or jumping over a rib. In none of these cases has the lung expanded above the newly formed roof.

Indication.—This type of thoracoplasty is advised in cases with a reasonable chance of cure by this procedure alone. If considerable disease is localized to the anterior segment of the upper lobe, this operation is now performed with resection.

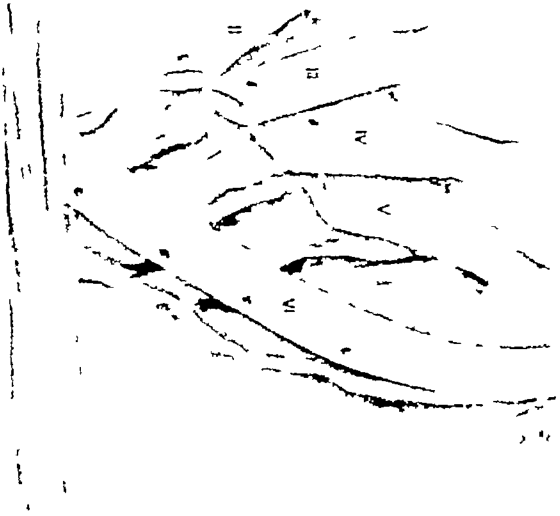
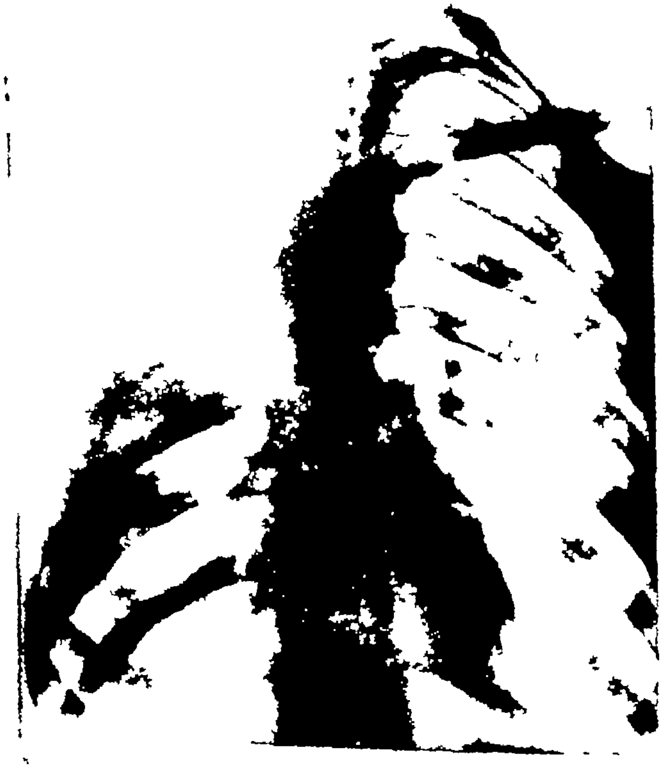
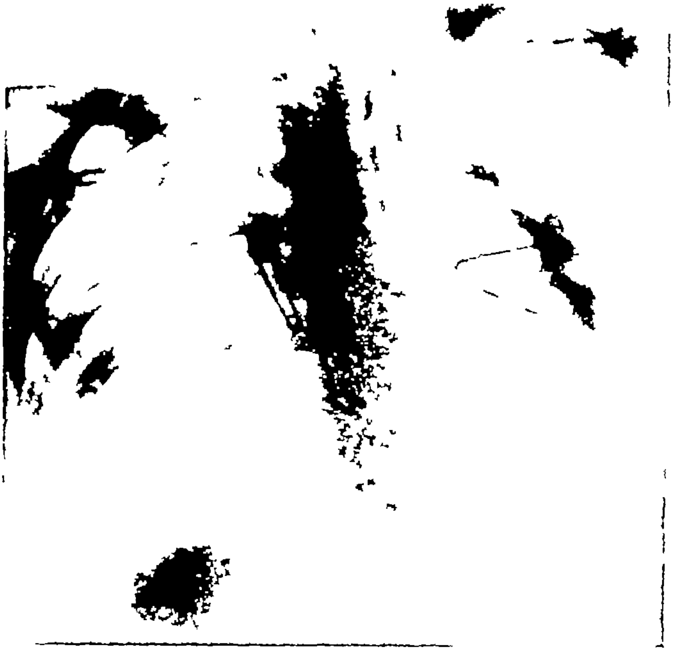


Fig. 11. A comparatively longer portion of ribs [illegible] to [illegible] are resected. The remaining an[illegible] [illegible] ribs are freed for some distance on their internal aspects subperiosteally [illegible] centripetal luxation.



[illegible]



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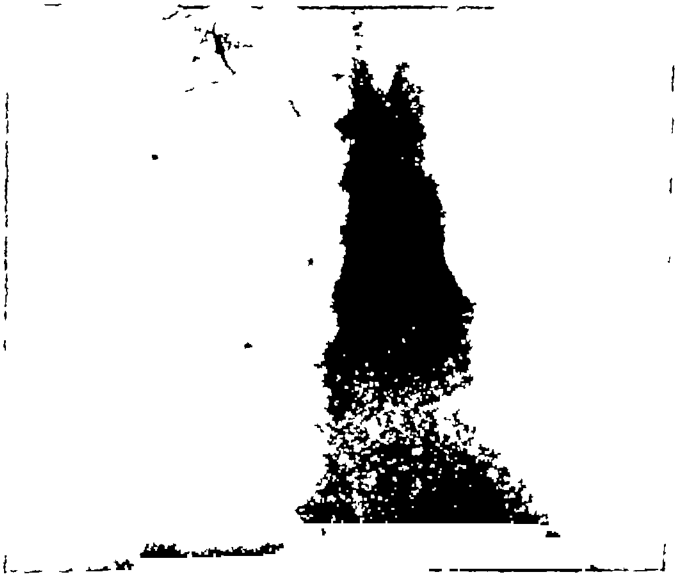

2

Fig. 17.—1, X-ray [illegible] woman who had [illegible] [illegible] ribs [illegible] fixed to the transverse processes of fifth and sixth thoracic vertebrae. The remaining ribs [illegible] fixed [illegible] the eighth [illegible] silk through drill holes. (1) [illegible] (2) [illegible] of apical pleura [illegible] (3) [illegible] drainage tube and the apex of the lung [illegible] film taken [illegible]

2, X-ray of the same [illegible] later. The apex of the left lung is above the [illegible]

1

[illegible]

Discussion.—I believe as much concentric relaxation of the diseased area as needed can be obtained by the new procedure. The ribs that were parallel have been brought to converge on the posterior part of the sixth rib (Fig. 10). If comparatively longer portions of ribs 3, 4, and 5 are resected and these as well as rib 2 are freed for some distance on their internal aspects subperiosteally, a considerable concentric retraction of the diseased area is permitted (Fig. 11). The first rib should, however, be left in its periosteal bed to prevent mediastinal re-expansion of the lung.

This thoracoplasty is a well-tolerated one-stage procedure with practically no possibility of re-expansion of the apex (Fig. 12). As the ribs are left in their periosteal sheaths interiorly, an eventually extended rib resection may easily be performed.

This operation was also performed as a preparatory operation for resection. At present, however, resection and thoracoplasty are practically always performed at the same operation.

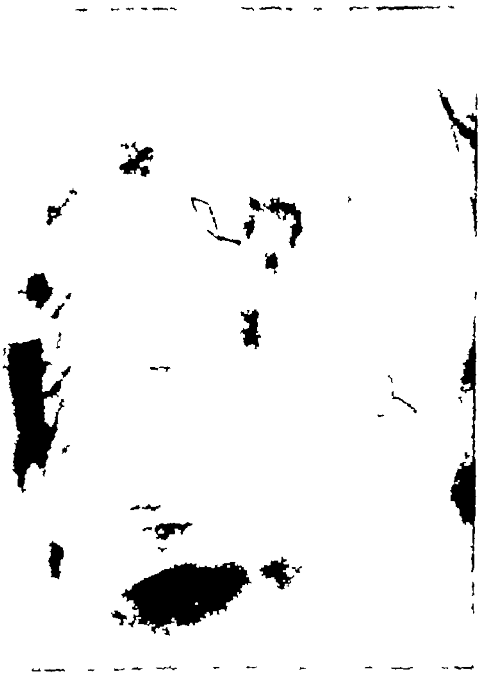

Fig. 11C.—(For legend see page 205.)

THORACOPLASTY IN COMBINATION WITH RESECTION

Results.—The new type of thoracoplasty has been performed in 100 cases in combination with resection. There was one postoperative death.

In 20 cases the first rib has been divided anteriorly, resected posteriorly, and fixed as close to the mediastinum as possible. It is advisable to follow this technique in cases when an extrapleural resection has been performed and there is danger of infection of the apicolysis space, and when it is felt important to prevent even slight re-expansion of the lung.

A

B

[illegible] A. This [illegible] lighted [illegible] on the left [illegible] performed [illegible] years before [illegible] the operation the maximal breathing capacity [illegible] liters per minute [illegible] per cent of the oxygen uptake and [illegible] per cent [illegible] minute ventilation on the right side. X-ray [illegible] after [illegible] upper lobe [illegible] with simultaneous thoracoplasty. The [illegible] ment of [illegible] which [illegible] the sixth rib with [illegible] The [illegible] fixation was performed [illegible] The patient tolerated the [illegible] well.

B. X-ray of the [illegible] patient [illegible] months after the operation.

In 50 cases the first rib has been left in place. This modification is somewhat easier and less time consuming to perform and is used in cases where after resection some expansion of the lung above the new thoracic dome is of no importance. If too short a piece of the second rib is resected there will be too large a space inside the curvature of the second rib with a re-expansion of the lung (Figs. 5 and 13). If, however, a longer piece is resected from the second rib making it as straight as possible it can be fixed close to the mediastinum. If then a careful fixation (Fig. 8) of the mediastinal pleura to the first intercostal muscle bundle is performed the lung will be kept below the new roof (Figs. 14, 15 and 16). These technical details have been found most important for a good result. In one case in which a giant cavity was opened during the resection a tuberculous infection occurred in the apicolysis space. This seems now to have been brought under control by conservative means. The cosmetic and functional result has been good (Fig. 17).

[illegible] month after right upper lobectomy and [illegible] and posteriorly [illegible] The apicolysis was carried down to the [illegible] sixth rib with [illegible] sutures and nylon [illegible] the apical pleura was performed. Five months after [illegible] per cent of the

[illegible] This type of thoracoplasty is now always used after resection [illegible] are removed and small nodules are [illegible] there in the lung a small roof thoracoplasty is also added for [illegible]

[illegible] has been observed in overexpanded lungs.

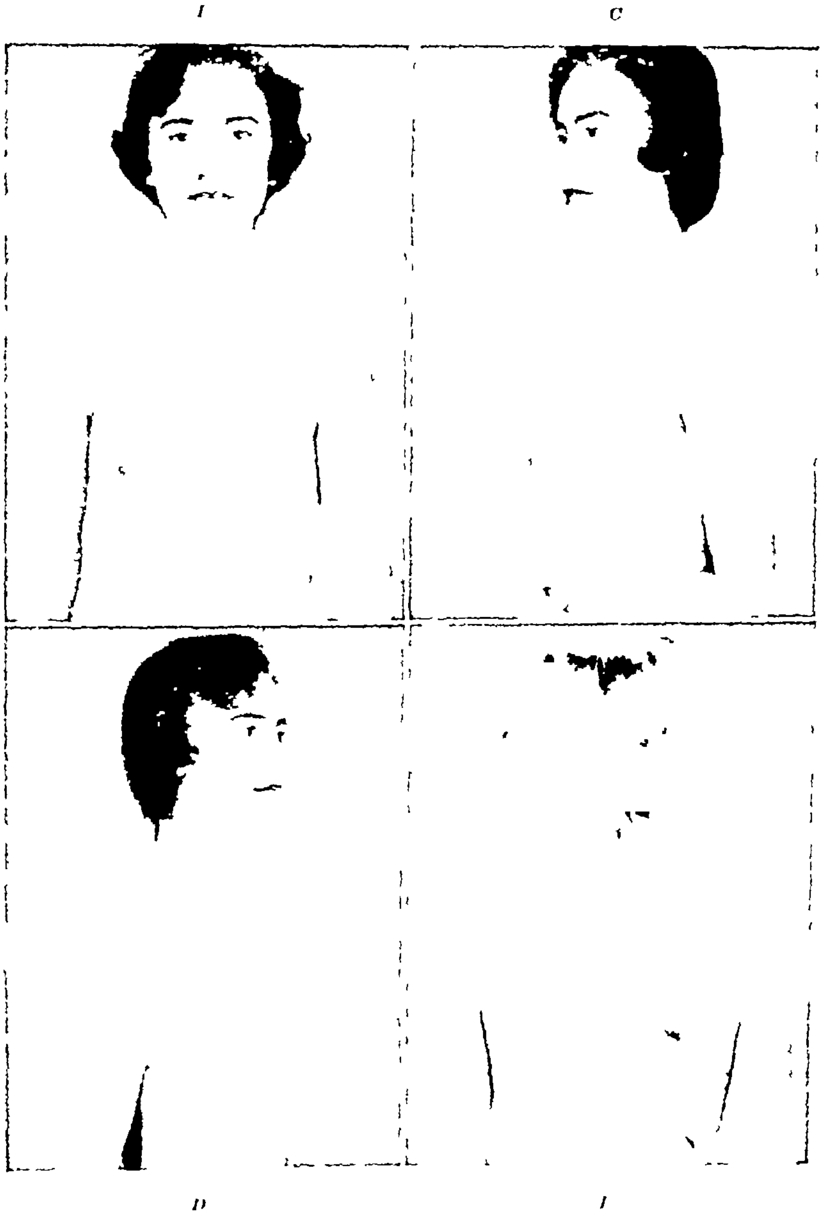

Fig. 17.—A-D, The same patient as in Fig. 1[illegible]. The cosmetic results has been good. Only a slight enlargement of the [illegible] the right clavicle can be noticed.

2. If the remaining lung tissue contains several fibrotic areas, it may not completely fill the chest cavity. Any intrapleural air pocket will be potentially dangerous because of infection.

3. A better function of the remaining lung tissue may be obtained. When a thoracoplasty is performed, the percentage of oxygen uptake on the operated side will often keep parallel to the ventilation. On the other hand, resection without thoracoplasty may result in a comparatively high ventilation and low oxygen uptake on the operated side. Thus the respiratory work on the operated side may be considered uneconomical.

Discussion.—As this type of thoracoplasty will result in a stable roof, paradoxical movements are excluded, cough is more effective, and atelectasis is rarely encountered.

Function studies including arterial oxygen determination during the immediate postoperative period are in progress.

The size of the thoracoplasty may be varied as found necessary. In young patients the costal cartilages are more easily bent, but the operation has been performed in several patients over 50 years of age, the oldest being 60 years old.

Summary.—A new technique for thoracoplasty is described and has been performed in 118 patients. There was only one postoperative death. This new thoracoplasty includes (1) resection of posterior parts of the ribs, (2) apicolysis to the hilum, (3) fixation of the ribs to the posterior part of rib 6 by stainless steel sutures through drill holes. When the sutures are tied, the costal cartilages are bent and a stable roof is obtained.

With the new thoracoplasty paradoxical movements are excluded and the cough is more effective. When used as a procedure per se, as much as a seven-rib thoracoplasty is well tolerated in one stage.

The combination of resection with this type of thoracoplasty is a well-tolerated procedure.

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LIPOID PNEUMONIA SIMULATING TUMOR

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CHARLES L. BICKHAM, M.D.,*** AND THEODORE WINSHIP, M.D.****
WASHINGTON, D. C.

LIPOID pneumonia is a chronic disease of the lungs caused by the ingestion of oil into the alveolar spaces. It was first recognized by Laughlen[1] in 1925. He reported the autopsy findings in three children who had received oily medications over a long period. Since his report a large number of cases have appeared in the literature in adults as well as in children.[2] Lipoid pneumonia is commonly encountered in the aged who use mineral oil to alleviate constipation. In the younger age group oil nose drops or sprays are the chief offenders especially when cocaine has been added to the preparation. In infants the disease has been reported following the aspiration of milk, vitamin oils, and oily nose drops.[3]

Recently the increasing incidence of lung cancer has been the subject of considerable speculation. Cases proved by tissue biopsy must be accepted but our experience at Garfield Memorial Hospital leads us to doubt the validity of cases of lung cancer not histologically proved. It is probable that some of the cases of reported lung cancer without biopsy proof are actually lipoid pneumonia. Despite the modern techniques now available there are times when it is impossible to distinguish preoperatively between two or more diseases of the lung. Such was true of the six patients to be presented in this paper. In the past small quantities of oil have been found on occasion in the alveoli of the lungs removed because of bronchiectasis or carcinoma but cases such as these were not included in this series. The cases comprising this report were studied carefully and no pathologic alterations were found except those resulting from the voluntary ingestion of oil. A bronchogram was not made on three of the patients and in two instances iodized oil did not enter the segment of lung involved because of occluded bronchi. The large amounts of oil found in the lungs of these six patients could only be accounted for by the voluntary ingestion of oil. Because of the clinical similarity between lipoid pneumonia and tumor the following cases are presented.

CASE 1.—M. W., a 65-year-old white woman consulted her physician on June 12, 1942, because she was not feeling well. A roentgenogram of her chest showed a discrete round area in the right mid lung (Fig. 1). *When she was admitted to the hospital July* 17, 1942 she had no symptoms referable to her chest and her physical examination was

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[1] Read for publication March 29, 194[illegible].

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****Senior Attending Pathologist, Garfield Memorial Hospital.

[illegible] negative. Bronchoscopic examination revealed a grayish mass almost blocking the [illegible] division of the right lower lobe. No bronchogram was made. The preoperative diagnosis was bronchogenic carcinoma. On July 27, 1942 her right lung was removed without complication. The lung weighed 750 grams and its surface was smooth [illegible] red and black. Cut sections showed a 4 cm. firm mass in the lower lobe with surrounding induration. The tissue comprising the mass was gray with flecks of [illegible]. There was atelectasis peripheral to the mass. The bronchi were patent except in the involved area. Microscopic examination of sections taken from the central portion of the tumor showed thick partially hyalinized fibrous bands separating the [illegible]. Lymphocytes and plasma cells were diffusely scattered throughout the fibrous tissue and there were occasional large aggregates of lymphocytes. The few residual [illegible] containing hyperchromatic nuclei attached to the walls of circular cavities [illegible] the alveoli. In addition to the small droplets of oil identified by the use of fat stains there were large globules of oil present in the thick alveolar walls. Her

Fig. [illegible]

[illegible] mass in right mid lung field.

[illegible] after right pneumonectomy showing [illegible] in the left lung.

[illegible] distant location. A communication with the [illegible] of Health. She had not been informed of the [illegible] long practice of taking mineral oil [illegible] in 1946 Fig. 2 revealed a mass similar [illegible] of mineral oil.

[illegible] in November 1948 with [illegible]

CASE 3.—F. S., a white man aged 53 years, was admitted to Garfield Memorial Hospital on Aug. 13, 1950, complaining of having had a cold for four weeks. This had been accompanied by fever and increasing fatigue. He had a chronic nonproductive cough and

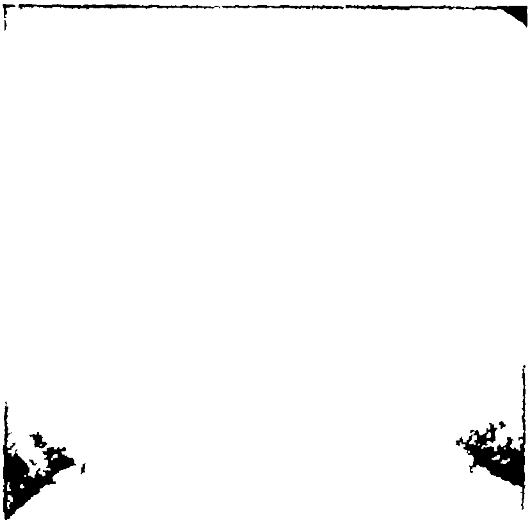


FIG. 3.

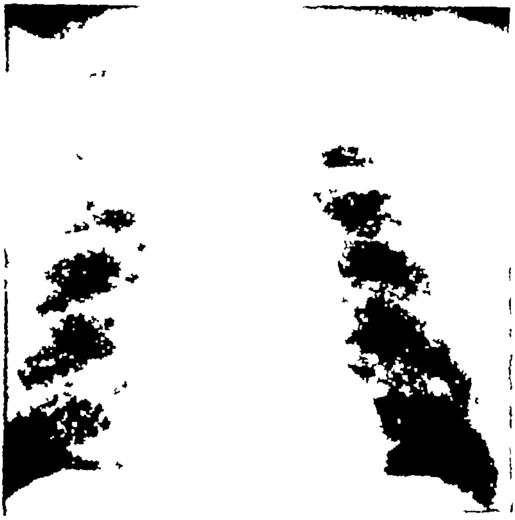


FIG. 4.

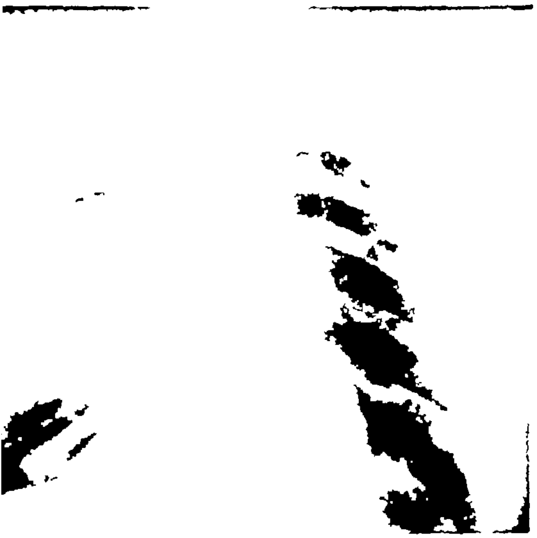


FIG. 5.

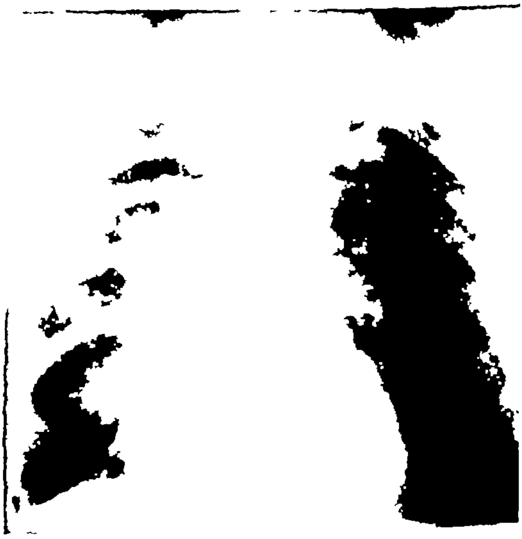


FIG. 6.

FIG. 3.—Roentgenogram in Case 2 showing a localized area of increased density in the right upper lobe.

FIG. 4.—Roentgenogram in Case 2 taken thirty-four days after the original roentgenogram (Fig. 3). Note the density in the right upper lobe which has [illegible] and [illegible].

FIG. 5.—Roentgenogram in Case 3 showing a normal appearing chest.

FIG. 6.—Roentgenogram in Case 3 taken [illegible] months after the roentgenogram (Fig. 5). [illegible] the large [illegible] appearing mass in the right lung.

[illegible] 1950 [illegible] (Fig. 5) [illegible]

[illegible] to percussion and numerous fine moist rales in the lower right lung field. [illegible] within normal limits. Bronchoscopic examination showed no [illegible] for some rigidity in the right lower lobe bronchus. Cytology and [illegible] for tubercle bacilli were negative. Examination of the chest on Aug. 14, 1950 (Fig. 6) [illegible] mass extending from the right sixth to twelfth rib posteriorly. [illegible] to be fixed. A bronchogram showed normal filling of the [illegible]. The [illegible] lymphoma with extension into the right lung or an unusual [illegible] in the right lower lobe. At operation on Aug. 17, 1950, the right lower [illegible]. The entire lung was densely adherent to the chest and the diaphragm [illegible] greatly enlarged. A frozen section diagnosis was equivocal but was [illegible]. A pneumonectomy was accomplished with difficulty because of [illegible]. The lung weighed 1000 grams. The entire surface was covered by fibrous [illegible] partially collapsed and bluish red in the upper lobe but was solid and grayish [illegible] lower lobe and inferior portion of the middle lobe. The interlobar fissures [illegible]. Cut section showed homogeneous spongy yellowish-gray tissue [illegible] all the lower lobe and approximately half the middle lobe. The bronchi were [illegible] but were patent throughout. Microscopic sections of the lower [illegible] middle lobes [illegible] alveoli devoid of lining cells and surrounded by wide bands of [illegible]. The alveoli contained large masses composed of desquamated alveolar lining [illegible] lipophages. Sections stained with Sudan III showed small particles of fat [illegible] and large quantities of fat in the alveoli. The patient died following [illegible]. Autopsy showed small amounts of fat present in the left lung and some of [illegible] were enlarged but there was no increase in the amount of fibrous [illegible] wall. After the death of the patient it was learned that he had taken [illegible] for [illegible] years. It was ascertained that he took a large draft of [illegible] every night and also upon rising in the morning.

Case [illegible] year-old white man was admitted to the hospital on Sept. 17, 1952, [illegible] physical examination which revealed a lesion in his right lung. The [illegible] of slight dyspnea but he had no cough or pain. The physical [illegible] essentially negative and the results of routine laboratory tests were [illegible] roentgenogram of the chest on Nov. [illegible], 1951 had demonstrated an [illegible] with a nodular border in the right middle lobe which had [illegible] Aug. [illegible], 1951. The major fissure was slightly [illegible] of the middle lobe. A bronchogram showed failure of [illegible] the middle lobe to fill. Tomographic study of the middle lobe [illegible] filled with air and surrounded by a homogeneous density [illegible] fibrosis. The lesion was believed to be either an [illegible]. A bronchoscopic examination revealed no abnormality. Cytol[illegible] showed no growth. On Sept. 17, 1952 the [illegible] with no difficulty and the patient made an un[illegible] segment of the middle lobe was firm, slightly [illegible]. The [illegible] division of the lower lobe presented [illegible] crepitant in the involved areas [illegible] which cut [illegible] walls were markedly thickened [illegible]. Most of the alveoli con[illegible] giant cells. In [illegible]

[illegible]

His history revealed increasing fatigue and a chronic productive cough for four years. Hemoptysis had occurred four times during the past six months and he had experienced vague epigastric distress periodically. He admitted having used oily nose drops regularly for over four years. The physical examination was essentially negative except for rales over the right lower lobe. Laboratory examinations were not helpful. Bronchoscopic examination revealed thickening and edema of the bronchi leading to the right lower lobe. The cytology and cultures for tuberculosis were negative. Roentgenogram of the chest on Aug. 28, 1953, showed a soft tissue density measuring approximately 5 cm. in diameter located in the posterior portion of the right lower lobe. A bronchogram showed filling of all the major bronchi except those in the region of the mass. The preoperative diagnosis was either lipoid pneumonia or tumor. At operation on Sept. 14, 1953, a mass was palpated in the right lower lobe and the adjacent part of the middle lobe. A frozen section diagnosis of lipoid pneumonia was made, and the middle and lower lobes were removed. Grossly, the lobes weighed 311 grams and were partially crepitant. Cut sections showed a 3 by 2.5 cm. poorly circumscribed, firm, light yellowish-gray mass in the basal portion of the lower lobe. In the bronchus leading to the diseased tissue in the lower lobe was an irregular 0.8 cm. concretion. Microscopically, the lesion consisted of masses of edematous fibrous tissue interspersed with partially collapsed alveoli. Deep in the fibrous masses were groups of fat-filled phagocytes, lymphocytes, and a few plasma cells. The alveoli contained a few lipophages and were partially lined by cuboidal cells. Some of the alveolar lining cells remained attached to the wall while others formed conglomerate masses in the alveoli.

CASE 6.—W. W., a 51-year-old white man, was admitted to Garfield Memorial Hospital on Feb. 5, 1953, complaining of a cold which had not responded to antibiotic therapy. He had had pain in the right chest and a severe cough for two months. Physical examination was negative except for a few moist rales in the right hilar area. Laboratory findings were within normal limits. Bronchoscopy revealed diffusely inflamed mucosa on the right side. Washings showed some suspicious cells and were negative for tuberculosis on culture. A bronchogram was not done. A roentgenogram of the chest showed enlargement of the right lung root. The appearance of the shadow was such that the possibility of a bronchogenic carcinoma must be considered. A right pneumonectomy was done on Feb. 6, 1953. There were many pleural adhesions and the hilar lymph nodes were enlarged. The lung weighed 875 grams and was crepitant except for a centrally placed 5 cm. mass in the right lower lobe. Cut section showed an ill-defined area of induration measuring 4 cm. in diameter with a small central cavity containing oily material. The wall of the cavity was ragged and about it was a thick layer of grayish-yellow, firm, finely granular tissue. Histologically, the alveoli were irregular in shape because of the thickened fibrotic alveolar walls. The alveoli contained a large number of lipophages and were lined by low cuboidal cells with prominent nuclei. The alveolar walls contained many fat-filled phagocytes and scattered lymphocytes with a few plasma cells and neutrophils. It was discovered after the operation that the patient had used approximately a pint of mineral oil a month for at least a year for relief of constipation.

While this series of cases is not large, the symptoms and findings are fairly characteristic of a larger group of nonsurgical patients with lipoid pneumonia found at Garfield Memorial Hospital during the past five years. The importance of this preventable disease should not be minimized because it is often disabling. The disease may sometimes be fatal. The autopsy findings on five patients who died of lipoid pneumonia at this hospital were recently reported (including our Case 3).

Only three patients in this series sought medical advice because of their symptoms. The others were referred for investigation because of asympto-

[illegible] lung lesions found on routine roentgenographic examination Most of the patients had rather vague indefinite complaints and no single complaint was *common to* all patients On questioning four had a chronic cough and two had slight pain in the chest One patient had repeated hemoptyses and one was slightly dyspneic

The diagnosis of lipoid pneumonia cannot be made on the basis of clinical findings alone Physical signs are not specific and vary with the size position and character of the lesion Clinical laboratory tests are equally unrewarding and serve only to rule out certain other diseases It has been *determined in a large series of cases* that *lipoid pneumonia occurs predominantly in the right lung* This is presumably due to the anatomic differences between the two lungs The right lung was involved in every patient in this series It has also been determined that the right lower and middle lobes are most frequently involved This was the case in this series the right upper lobe being involved in only one instance Only one of the patients in this group of six was a woman although in larger series the sexes are almost equally divided The ages of our patients ranged from 46 to 65 years

In all but *one* case the history of oil ingestion was obtained after the oil had been found in the resected lung According to the histories the disease was caused by mineral oil taken for the relief of constipation in four cases and by nose drops and petrolatum each in one instance

A pneumonectomy was performed on three of the six patients because of extensive involvement of the disease in one case and the medial location of the tumor in the other two cases The right middle and lower lobes were removed in two cases because of extensive disease and the right upper lobe only was removed in the patient who had localized tumor In four patients [illegible] extensive pleural adhesions were present which were usually unrelated [illegible] the site of the disease Lysis of adhesions slowed the operating time be[illegible] great vascularity The hilar and mediastinal lymph nodes [illegible] in two instances Histologically these nodes were [illegible] and the hilar nodes in Case 3 contained oil All the pulmonary [illegible] were described at the time of operation as being firm and rubbery [illegible] dimpling of the pleura over the mass Lipoid pneu[illegible] in any of the cases at the operating table because [illegible] carcinoma Lipoid pneumonia was suspected in [illegible] were requested The frozen section diagnoses [illegible] the early cases but later lipoid pneumonia was [illegible] appearance of the cut section of the lung [illegible] quickly made which confirmed the diagnosis [illegible] from beneath go into the pleura [illegible] complications and [illegible] at the [illegible] informed of the [illegible] She cared [illegible] years [illegible] taken mineral oil for relief. The roentgenogram taken seven years after pneumonectomy showed an area of density in the left lung field similar to that seen on the right three years before.

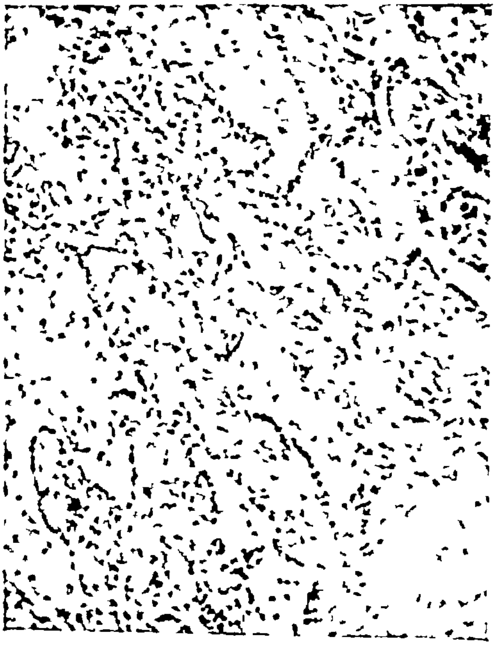
In general, the roentgen features are those of fibrosis and consolidation. The disease is usually multilobular and may remain unchanged for years. The fibrosis consists of fine linear and small nodular densities which may or may not reduce the size of the lobe. The appearance is that of spun glass and it may extend to the pleural surface, however, pleural effusions are rare. By means of Bucky film and a fine focus tube an area of apparent consolidation can be shown to contain air and present the spun-glass appearance. This finding is of great importance in diagnosis, for it rules out a solid tumor or complete collapse. The lower lobes, particularly the right, are the usual sites of the disease, but the axillary portions of the upper lobes may also be involved. The disease may affect an entire lobe and produce an airless appearance, for example, involvement of two middle lobes has been seen, one occurring coincidental with sarcoid and another in a patient without other pathology. One case showed complete collapse of the middle lobe and the bronchi could not be identified grossly. Lipoid pneumonia may simulate atypical pneumonia, lobar pneumonia, tuberculosis, neoplasm, infarction, metastatic lesions, or bronchiectasis. In every case in this group there was either apparent bronchial occlusion or a nodular mass resembling tumor.

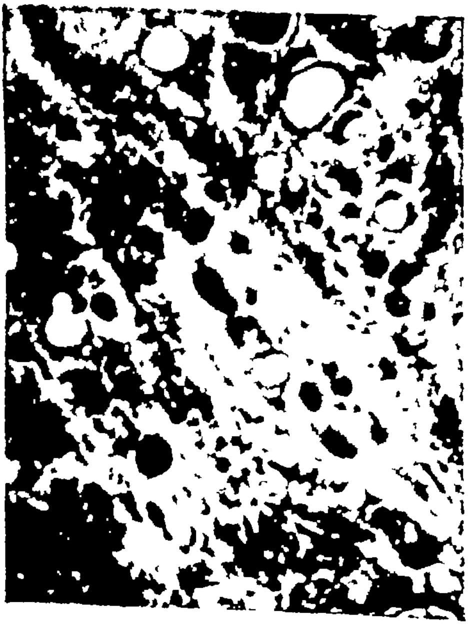
The diagnosis of lipoid pneumonia is made on routine hematoxylin-and-eosin-stained tissue, though fat stains are always used for confirmatory purposes. This diagnosis is not made when the sudanophilic material is found only in the alveoli and alveolar walls, for this is usually due to preoperative iodized oil studies. When sudanophilic material is found in the fibrous tissue some distance from the adjacent alveoli it is considered to be ingested oil. Control lungs subjected to iodized oil studies preoperatively have not shown penetration of oily substances beyond the alveolar walls. It is known that varying amounts of intra-alveolar oil are removed by physiologic and mechanical means. Intracellular oil was found in the sputum of one patient for a month after the introduction of iodized oil into the lungs for diagnostic purposes. Between August 1950 and November, 1953, a period of three years and three months, fifty-seven patients were operated upon at Garfield Memorial Hospital for primary carcinoma of the lung. During the same period three patients were operated upon for lesions which ultimately were proved to be lipoid pneumonia. Though these figures are too small to be of statistical significance they indicate the difficulty in establishing a correct preoperative diagnosis. The figures also suggest that lipoid pneumonia is a relatively common condition.

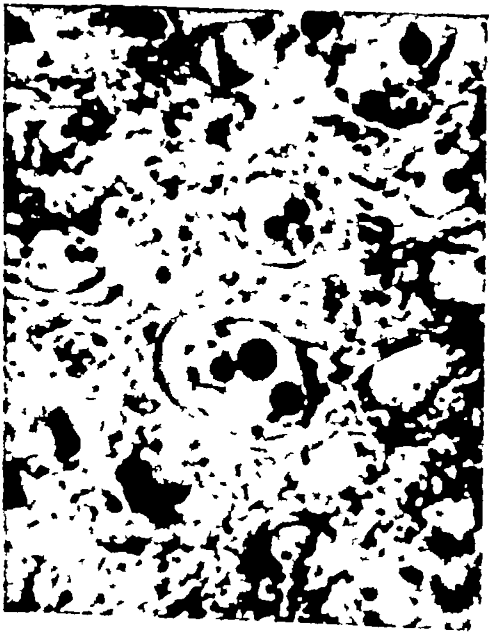
A strong index of suspicion is the best aid to the diagnosis of lipoid pneumonia. This is shown by the relatively large number of such cases found at Garfield Memorial Hospital in recent years. It is important to make a diagnosis in suspicious cases before undertaking a major operative procedure, for surgery is probably not the treatment of choice in all cases. A diagnosis of lipoid pneumonia may be made on the basis of a satisfactory history of the

Fig. 7

Fig. 8







[illegible]

ingestion of oil, consistent roentgen findings and the finding of oil within phagocytes in the patient's sputum. The technique for collecting specimens of sputum for examination is important. The patient's sputum must be from the bronchi and should be collected in a clean glass container prior to eating breakfast. Smears stained with Sudan III are positive when particles of sudanophilic material are present within the phagocytes. Extracellular fat is of no significance.

Most patients who use oily medications apparently have no need for active treatment. Patients who develop dyspnea or shortness of breath should be treated symptomatically and advised to stop medication. Surgery is indicated for any patient who gives a history of ingestion of oil whose sputum contains oil and in whom a pulmonary lesion cannot be differentiated roentgenologically from a tumor. The best treatment is prevention.

We wish to express our appreciation to Dr Roy G Klepser for permission to include Case 1 and to the Armed Forces Institute of Pathology for Case 2.

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Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty fifth Annual Meeting of the American Association for Thoracic Surgery will be held April 24, 25, and 26, 1955, in Atlantic City, New Jersey Headquarters will be at the Chalfonte Haddon Hall

Requests for Hotel Reservations

These should be mailed directly to Miss Doris Sears, Convention Manager, Chalfonte Haddon Hall, Atlantic City, New Jersey Please mention this Association, the type of accommodation desired, date and approximate hour of arrival If accommodations are desired elsewhere in Atlantic City, please communicate directly with the hotel of your choice

Thoracic Surgical Forum

By vote of the membership, the Forum is to be continued for the presentation of short papers on current thoracic research, experimental problems, anatomical studies and modified or new surgical techniques The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers or to suggest their transferral to the regular program Papers at this session will be limited sharply to ten minutes, including the showing of lantern slides or other illustrative material At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper

These papers will be published together in one issue in the JOURNAL OF THORACIC SURGERY Maximum length 3,000 words without illustrations If illustrated, an appropriate number of words must be subtracted for each cut used

Abstracts for Papers

Abstracts for the presentation of papers at the 1955 meeting, including papers before the Forum, must be received on or before Dec 15, 1954, otherwise they will not be considered by the Program Committee

Abstracts should be labeled "For Thoracic Surgical Forum," or "For Regular Program"

Five, repeat, five copies of each abstract must be sent to the Secretary of the Association, Dr Paul C Samson, 3950 Happy Valley Road, Lafayette, California They should not be sent to the Editor

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec 15, 1954, otherwise, the applications will be deferred for consideration until 1956

Applicants must be sponsored by three Active or Senior members of the Association In addition to the signatures on the application form, the sponsors must forward *a separate* letter concerning the applicant directly to Dr Lyman A Brewer, III, Chairman of the Membership Committee, 2010 Wilshire Blvd, Los Angeles 5, Calif

Completed application forms and the sponsoring letters *independently* sent by the three sponsors must be received by Dr Brewer not later than Dec 15, 1954, to be considered for action in Atlantic City

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year

The Journal of Thoracic Surgery

Vol. 28 SEPTEMBER, 1954 No. 3

SURGICAL FORUM

This issue of the JOURNAL OF THORACIC SURGERY is devoted to the fifteen papers constituting the Forum. It is expected that every year at about this time a whole issue of the JOURNAL will be given up to a similar group of papers with their discussions. The idea of a Surgical Forum was put into practice more than a decade ago with the American College of Surgeons at the instigation of Dr. Owen Wangensteen. *The original conception was that it should* constitute an opportunity for young men, perhaps even too young to qualify for fellowship in the College, to present the results of their original researches on underlying scientific aspects of surgery. From the beginning the Forum has been a great success and unquestionably it has inspired much high-grade investigation of surgical problems.

The idea of the Forum has been taken over by other societies. This is the first year that the American Association for Thoracic Surgery has tried the experiment.

THE EDITOR

Original Communications

USE OF THE ENDOTRACHEAL TUBE IN PULMONARY EDEMA

WATTS R WEBB, M D (BY INVITATION), SANATORIUM, MISS , AND
GUY D CAMPBELL, M D (BY INVITATION), NEW ORLEANS, LA

PULMONARY edema occurring during or immediately following operations has been infrequently described, yet sporadic reports[3, 9, 22] indicate that it is not rare As we have personally seen seven cases, three elsewhere and four during the past eighteen months at the Mississippi State Sanatorium, we feel that it represents a greater problem than is evident at first inspection The first three patients treated by conventional medical measures died In the four patients treated by the method described below it was possible to clear completely the pulmonary edema, three recovered fully

Regardless of the etiology of the pulmonary edema—whether cardiac, anoxic, or toxic—one common factor, partial or complete obstruction by the edema fluid, quickly develops If these patients die, it is usually by drowning

Yet nearly all reported medical regimens overlook the important possibility of mechanically removing the edema fluid Ordinarily, its removal is dependent upon the cough of the patient, which is rarely effective, and upon lymphatic absorption Lymph flow is relatively slow even at best, while the high protein content of the edema fluid[8] prevents its capillary reabsorption

As a result of the ensuing bronchial obstruction, there develops a variable degree of anoxia Anoxia causes both pulmonary-artery hypertension[21] and capillary dilatation[7, 10] leading to congestion stasis, mucosal edema, and further transudation of edema fluid with increased obstruction and greater anoxia It is extremely important to interrupt this cycle at some point, and the mechanical removal of the accumulating transudate appears to be the most feasible and rewarding

The method we have used consists of a utilization of demonstrated principles and existing equipment An endotracheal tube with an inflatable cuff is inserted into the trachea with the patient still asleep or under local anesthesia if he is awake Oxygen is administered under a positive pressure of 5 or 6 cm of water[4, 5] Brief periods of suction through the endotracheal catheter with a smaller urethral catheter are repeated as frequently as may be necessary We have at times had to suction a patient as often as once each minute and found that, with a little practice, it is quite possible to discontinue the positive pressure oxygen for only about five seconds during each aspiration In addition, all the usual adjunctive measures have been used including intravenous digitalis and aminophyllin, restriction of fluids, mercurial diuretics, rotating tourniquets on the extremities, and actual phlebotomies

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From the Mississippi State Sanatorium Sanatorium Miss

Read at the Thirty fourth Annual Meeting of The American Association for Thoracic Surgery at Montreal Quebec May 3 to 5 1954

CASE REPORTS

CASE 1.—N. F. M., a 17 year old white woman, was admitted on Oct. 27, 1952, with an [illegible] history of universal bronchiectasis of the left lung following aspiration of a piece of [illegible]. The laboratory data including the electrocardiogram were all normal. The [illegible] sputum was reduced to almost nothing by antibiotic therapy. On Nov. 3, 1952, a left pneumonectomy was performed requiring two and one half hours. The lung was extremely adherent and was freed with great difficulty. The blood loss was rather marked and [illegible] cc. of citrated whole blood was administered intravenously. Extremely profuse secretions required frequent tracheal aspirations to keep the airway clear, and undoubtedly periods of anoxia occurred. Approximately one and one half hours after the incision frothy pink fluid was noted flowing from the endotracheal tube in such quantities as to require almost constant aspiration. Postoperatively the patient was aspirated almost every minute for over an hour, every two to three minutes for the next two hours, and then at five to ten minute intervals until the endotracheal tube was removed seven hours after the operation. The patient in addition received Cedilanid and aminophylline intravenously and [illegible] intramuscularly and continuous positive pressure oxygen. Rotating tourniquets were used on the extremities. The postoperative electrocardiogram showed a supraventricular tachycardia and diffuse ischemia. The blood counts on the first postoperative day showed 4.6 million red blood cells with 98 per cent hemoglobin. The postoperative course was uncomplicated except for a low grade fever that gradually subsided. The patient remains in excellent health and is completely asymptomatic.

COMMENT

While cardiac failure may have been partially responsible, it is believed that anoxia from the pulmonary secretions obstructing the airway was the prime cause of the pulmonary edema here. In addition the marked reduction in the pulmonary capillary bed by the pneumonectomy,[1-20] the administration of intravenous fluids, and the anoxia all tend to produce pulmonary hypertension. This patient was aspirated approximately one hundred and fifty times with an estimated 5 cc. of fluid and a larger quantity of froth being obtained each time during the early period. The importance of this quantity of fluid is magnified of course in the patient with only one lung.

CASE 2.—[illegible] 17 year old white girl was admitted Nov. 21, 1952 for universal [illegible] of the left lung. The electrocardiogram revealed myocardial damage with [illegible] was corrected with two preoperative transfusions [illegible] prior to operation. The preoperative preparation [illegible] nothing. On Dec. 15, 1952 a left pneumonectomy re[illegible] adhesions and many enlarged lymph nodes [illegible] of citrated whole blood was given [illegible] after the incision the endotracheal tube became obstructed [illegible] the patient with a new tube. During the [illegible] completion of [illegible] endotracheal [illegible] Continuous [illegible] positive pressure [illegible] and aminophylline [illegible] the extremities [illegible] improved to within normal limits Blood counts on the first postoperative day showed 4 76 million red blood cells with 84 per cent hemoglobin The postoperative course was uncomplicated thenceforward and the patient remains completely asymptomatic

COMMENT

In this case there was evidence of pre-existing cardiac disease, but the precipitating factor appears to have been the anoxia secondary to pulmonary secretions and the partially obstructed endotracheal tube The response to treatment was rapid, and only about 55 aspirations were required postoperatively before the pulmonary edema was controlled Even so this removed an estimated 250 c c of fluid from a child weighing only 30 kilograms and having only one lung

CASE 3—M R, a 23 year old white woman, had residual nodular and bronchiectatic tuberculous disease of the entire left lung after long term antibiotic therapy All the laboratory data were normal except for a marked anemia which was corrected with 1,000 c c of citrated whole blood given one week prior to operation

On Aug 13, 1953, a left pneumonectomy and nine-rib plombage thoracoplasty were performed The operation took approximately three hours, and 2,750 c c of citrated whole blood was given during the procedure No abnormalities were noted until the patient was extubated Then frothy, pink fluid was observed and the chest developed moist, inspiratory râles A nasotracheal tube with an inflatable cuff was inserted and oxygen at a positive pressure of 5 cm of water was started Mercuhydrin was given intramuscularly, and Cedilanid and aminophylline intravenously Tourniquets were rotated on the extremities and 500 c c of blood was withdrawn from an anticubital vein For the first hour aspirations were required every two minutes, obtaining an estimated 5 c c each time After this less fluid was obtained, and it was possible to remove the endotracheal tube five hours after the completion of the operation On the first postoperative day, blood counts revealed 4 43 million red cells and 98 per cent hemoglobin The postoperative course thenceforward was completely benign The right lung remained stable and the patient was discharged with negative sputum studies

COMMENT

The etiology of the pulmonary edema is not certain in this case No anoxia was recognized at any time The blood replacement was apparently in excess of blood loss, and may have caused pulmonary hypertension The patient's response was immediate, and less than 50 aspirations were required to obtain clinical clearing of the lungs

CASE 4—W H C, a 42 year old white woman, was passed for a left pneumonectomy because of extensive tuberculous bronchiectasis All laboratory data were normal except for an anemia, which was corrected with 1,000 c c of citrated whole blood, the last pint being given three days prior to operation Preoperatively the patient denied all cough and sputa

On Aug 24, 1953, a left pneumonectomy requiring two and one-half hours was performed Mobilization of the lung was difficult because of thick vascular adhesions, 2,250 c c of citrated whole blood was given intravenously During the early dissection, profuse purulent secretions mixed with blood poured into the trachea requiring very frequent aspirations The bronchus was clamped as soon as possible, one hour after the incision The pulmonary artery was occluded two or three minutes thereafter No further difficulty was noted until the completion of the procedure when the aspirated fluid appeared thin, frothy, and pink [illegible] in the remaining lung. The patient was immediately [illegible] Morphine [illegible] Rotating tourniquets were applied to the extremities [illegible] oxygen was started with aspirations being performed every two or three [illegible] next several hours. Over 80 aspirations were performed during the first four [illegible] large amounts of fluid being obtained during the entire period. Six hours [illegible] the pulmonary edema was slowly subsiding but not as rapidly as [illegible] 400 c.c. of blood was withdrawn from the antecubital vein. At this [illegible] blood pressure fell precipitously and it was necessary to add norepinephrine to [illegible] to maintain the blood pressure. Bronchial aspirations were performed there[illegible] intervals as the pulmonary edema appeared to have subsided. Blood [illegible] postoperative day revealed 4.5 million red blood cells and 82 per cent [illegible]

The postoperative course was marked by high fever and an unstable blood pressure [illegible] larger amounts of norepinephrine to prevent hypotension. The [illegible] progressively poorer and she died on the third postoperative day.

COMMENT

Again anoxia appeared to play the dominant role in the precipitation of the pulmonary edema. No cardiac damage was detectable and the blood administration probably did not exceed blood loss. A serious error was made in reducing the blood volume by phlebotomy after the patient had begun to improve even though that improvement was slow.

DISCUSSION

As early as 1880 MacEwen[1] described the use of endotracheal tubes as being preferable at times to a tracheotomy. Kuhn[2] in 1912 described the use of [illegible] wide bore endotracheal tube as an avenue for suction with a small bore catheter. Since then others[3-6] have described and utilized modifications [illegible] this method with great success in the removal of postoperative or post[illegible] from the tracheobronchial tree. Others[illegible] have [illegible] the extreme importance of mechanically removing various [illegible] such as secretions, blood, pus, or aspirated matter from the [illegible] the simple aspirating catheter, the bronchoscope, or a tracheotomy.

[illegible] however, has been written on the utilization of this method [illegible] In [illegible] of the many experimental and clinical papers on [illegible] few even mention the possibility of treatment by [illegible] Ward and Horner produced pulmonary [illegible] and did find improved results in those which [illegible] through a tracheotomy. A tracheotomy for [illegible] effective. It is, however, neither [illegible] than the endotracheal tube and [illegible] such as the [illegible] through the tracheotomy.

[illegible] first [illegible]

tracheal aspiration becomes extremely brief. The positive pressure oxygen, as has been pointed out,[4, 5, 10] is of itself of great value. The oxygen under pressure combats bronchospasm and mucosal edema as well as directly increasing the intra-alveolar pressure which helps prevent transudation of fluid from the capillaries into the interstitial tissues and air passages of the lungs. In addition, the increased pressure retards pulmonary blood flow, thereby reducing the pulmonary capillary blood pressure.

It has been amply demonstrated that the endotracheal tube can be left in place for a period of days without causing great tracheal or laryngeal damage.[12, 19] It is our preference, if the tube is to remain in place longer than forty-eight hours, to perform a tracheotomy which is much more satisfactory for removing the crusted secretions that inevitably seem to form.

The adjunctive measures that have been used have been of presumptive but unproved value in these cases where no definite cardiac failure could be demonstrated. Digitalization, however, in pulmonary edema caused by phosgene poisoning, has been shown to augment the heartbeat, clear up the irregularities, and keep the heart beating after respiratory failure in contrast to the undigitalized heart.[20] At the time of an acute episode as described above, one may be unable to rule out the possibility of cardiac failure and so use all the methods of treatment effective for all contingencies.

Mercurial diuretics probably do not act fast enough to help in these cases. There is some doubt that their action is at all marked in the immediate postoperative period when kidney function is depressed by the anesthetic and hormonal factors.

Ethyl alcohol vapor, as described by Luisada,[17] may be a further adjunct of great value. Any transudate in the air passages forms a froth as it is mixed with the mucus by the respiratory eddy currents. This froth assumes a volume many times that of the original water and mucus with a much greater obstructive potential. The aspirating catheter does not remove all of the fluid at any one time and then only that in the trachea and larger bronchi. Alcohol vapor, by lowering surface tension, can prevent froth formation in the smaller bronchioles and alveoli and thus aid in averting subsequent anoxia.

Drugs, such as hexamethonium, which act by reducing the peripheral arteriolar resistance, have been found effective in the treatment of pulmonary edema from congestive left-heart failure.[26] Their use in surgical patients, however, will have to be carefully evaluated because of the associated tendency to lower the blood pressure.

Should shock be superimposed, as is prone to happen, the problem becomes much more complex. Two of the early cases (not reported here) died of shock while being treated for pulmonary edema. Many of the measures beneficial for one are deleterious to the other, as for example, the positive pressure oxygen and the reduced blood volume from phlebotomy may be instrumental in precipitating or aggravating shock in an unstable vascular system. This was graphically demonstrated in our fourth case. In this situation of combined pulmonary edema and shock, a mechanical heart-lung preparation well might be lifesaving. These patients can usually be kept alive until the necessary attachments can be made into extrathoracic arteries and veins. Such an episode is often acute with an early favorable response to be anticipated. Similarly a good ultimate prognosis may be expected if there be no marked underlying cardiac disease or if pre-existing valvular disease had been corrected at operation.

While we have not had occasion to utilize the endotracheal tube on nonsurgical patients in pulmonary edema as from cardiac failure, we do feel that the problems offered are very similar and hardly more complex than those offered by a pneumonectomized patient. As the necessary equipment is readily available in nearly every hospital and the intubation can be quickly accomplished under local anesthesia, there is no significant reason why this method should not be utilized successfully in the cardiac patient in severe acute pulmonary edema. Obviously it is not necessary or desirable in all

SUMMARY

1. As the lethal factor in pulmonary edema is usually the accumulating fluid itself, we have utilized the indwelling endotracheal tube as an avenue for aspirating this fluid and for providing oxygen under constant positive pressure.

2. This method has been proved successful under the most trying circumstances by clearing the pulmonary edema which developed in four patients during or immediately following pneumonectomy.

3. Adjunctive measures are evaluated as to their probable aid and possible dangers.

4. Shock is a frequent complication of the treatment of pulmonary edema and is briefly discussed.

5. The method described should have applicability in most cases of pulmonary edema irrespective of the medical or surgical etiology.

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A SIMPLE SHUNTING TECHNIQUE FOR SURGERY OF THE AORTIC AND PULMONARY VALVES AND PROXIMAL GREAT VESSELS

AN EXPERIMENTAL STUDY

FREDERICK S. CROSS, M.D. (BY INVITATION), EARLE B. KAY, M.D., AND
RICHARD D. JONES, B.A.
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THE DEVELOPMENT of hypothermia and mechanical pump-oxygenators has progressed to the point where successful clinical trials are being reported in increasing numbers. Yet there are limitations of applicability inherent in both of these adjuncts to cardiac surgery which suggest that other techniques should still be investigated.

It has been the purpose of this study *to develop and evaluate plastic shunts* to bypass the circulation around the aortic and pulmonary valves and proximal great vessels in order to provide a simple method to approach these valves in a dry field and primarily to carry out surgery on the great vessels at the base of the heart.

The use of shunts to bypass isolated segments of the aorta is not new. It has been described in 1910 by Carrel[1] and more recently by Clatworthy and Varco, Shaffer and Hardin, and by Hubay and associates. However, previous investigators have done very little on shunting directly from the heart to the aorta and pulmonary artery. Carrel in 1910 mentioned several experiments in which he shunted blood from the left ventricle to the aorta successfully for [illegible] in several dogs. His mortality, however, was prohibitively high. [illegible] and associates have reported a satisfactory method [illegible] from the right ventricle to the pulmonary artery. To [illegible] procedure in which simultaneous shunting of both sides of the [illegible] has been reported.

DESCRIPTION OF SHUNTS

In [illegible] design of the present shunts rather [illegible] which included adequate diameter [illegible] [illegible] readily [illegible] [illegible]

[illegible]

These criteria were met by the shunts illustrated in Figs 1 and 2 They are constructed of Tygon plastic molded over glass tubing of the desired shape, in a hot water bath A single leaflet type valve is constructed into the shunt to take the place of the aortic and pulmonic valves in preventing regurgitation of blood back into the ventricles These valves are made of silicone rubber, and are held in place with vinyl electrical tape Since it is impossible to insert the Tygon tubing directly into the aorta and pulmonary artery in a satisfactory manner, flanged stainless steel T-adaptors (Fig 1) are used in which the combined cross sectional area of the two outlet arms is equal to the cross sectional area of the inlet stem Through the incorporation of this principle, the blood flow through the adaptors is not cut down, the adaptors are easily inserted, and an output flow in two directions from the point of insertion is provided permitting better distribution of blood

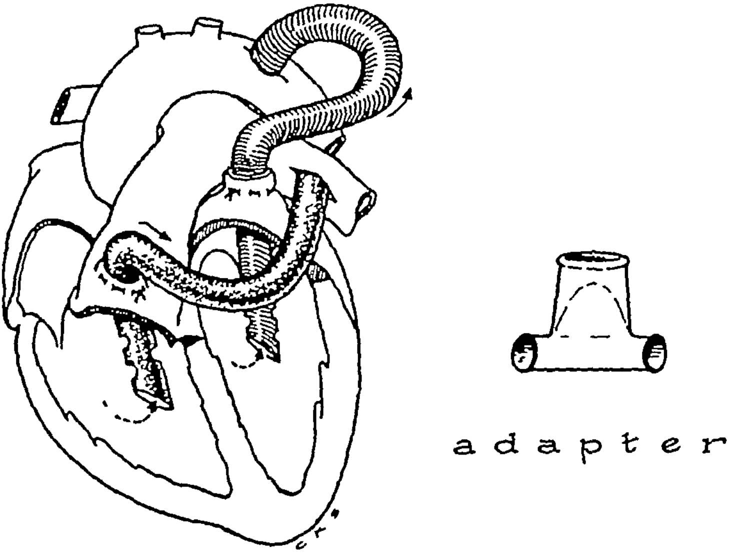


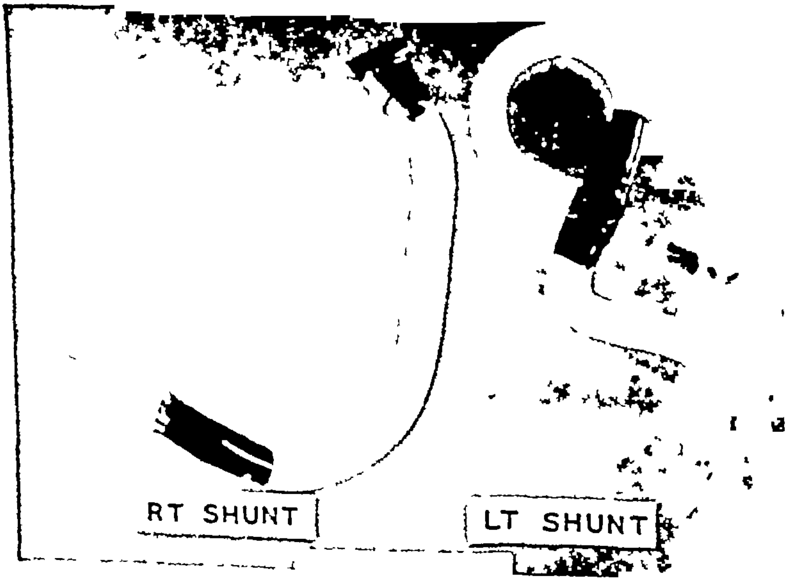
Fig 1 —Semidiagrammatic drawing of shunts in place. Note the resulting surgical accessibility of the great vessels at the base of the heart. Insert shows special adaptor for insertion into aorta and pulmonary artery

The right-sided shunt is essentially C-shaped to permit it to swing down toward the apex of the heart and away from the operating area at the base The left-sided shunt is in the form of a rather complicated loop which allows easy adaptability to the short and varying distance between aorta and the left atrial appendage into which it is inserted The ventricular ends of the shunts are tapered, and have multiple perforations to minimize the possibility of complete occlusion by apposition to the ventricular walls

METHOD

In healthy mongrel dogs under Nembutal anesthesia, the left chest is entered through the fifth interspace, respirations being maintained by means of a

Bureau of Mines Neophore valve connected to a tank of 100 per cent oxygen. The pericardium is incised parallel to the phrenic nerve from above the aortic arch to the apex of the heart. Retention sutures of 3-0 silk are placed to retract the pericardium and are anchored along the sternal edge of the incision. The pulmonary artery and ascending aorta are dissected out and stripped of fat and pericardium. The descending aorta for a distance of about 4 cm. below the left innominate is likewise dissected up. The left pulmonary artery is then isolated from the bifurcation to the point where it disappears into the left upper lobe as the lower lobe artery. The segmental arteries to the left upper lobe are occluded with 2-0 silk sutures looped but not tied for temporary occlusion. Purse-string sutures of 0 silk on an Atraumatic needle are placed in the infundibular area of the right ventricle and about the base of the left auricular appendage and affixed to Rummel tourniquets for securing the proximal ends of the shunts in the ventricles.



[illegible] electrical tape used in [illegible] to [illegible] tying.

[illegible] shunts were placed directly into the left [illegible] excessive hemorrhage, difficulty of insertion [illegible] or coronary air embolism precluded [illegible]. Therefore the approach to the left ventricle [illegible] which is advocated. All the [illegible] used by [illegible] The left [illegible]

[illegible] The segment [illegible]

by Potts ductus clamps and a longitudinal incision made The T-adaptor of the right-sided shunt is inserted into the artery and held in place by 2 0 silk ligatures around the limbs of the T By this method the pulmonary circulation to the right lung is never occluded during the insertion An incision is then made within the area of the purse-string suture in the right ventricle which is enlarged by finger insertion As the finger is withdrawn, the tapered end of the right shunt is slipped easily into the ventricle and the purse string tightened with a minimal blood loss

The left shunt is inserted in essentially the same manner between the left ventricle, via the left atrial appendage, and the descending aorta During the insertion, the aorta is occluded for an average of five minutes, which is well within the safe period determined by Gross and Hufnagel [4]

After placement of the shunts, the heart is allowed to stabilize, and any blood loss is replaced before the proximal great vessels are cross clamped to divert the full circulation through the shunts With the shunts working, observations were made on changes in heart size, rate, rhythm, and in some instances changes in intraventricular, aortic, and pulmonary artery pressures were measured by means of a Statham strain gauge and Keithley amplifier to test the efficacy of the shunts In addition, survival experiments were carried out after total occlusion of the great vessels at the base of the heart for periods of from 30 to 70 minutes

RESULTS

Twenty-six dogs have been shunted successfully for periods ranging from 30 to 80 minutes Of these, 16 dogs were acute experiments in which no attempt was made to save the dog The other 10 dogs were in the category of survival experiments In these dogs the shunts were removed after carrying the full circulation for periods of 30 to 70 minutes and the animals were allowed to recover Of these 10 dogs, 9 showed complete recovery with no apparent residual effects from the operation such as hind limb paralysis or cerebral manifestations during follow-up periods ranging from one week to several months One dog died in about twelve hours of unexplained causes

No significant changes in the hearts themselves were observed during the time the shunts were carrying the full cardiac output In most instances there were varying degrees of dilatation apparent immediately after the great vessels were cross clamped which subsided to near normal as the circulatory dynamics readjusted No consistent change in the cardiac rate or rhythm could be detected

The plastic tubing finally adopted in this series of experiments measured 5/16 inch or 8 mm inside diameter Shunts of this size were found to be the most consistently satisfactory in the 25 to 35 pound dogs used In dogs under 25 pounds, it was difficult to insert the shunts because of the small size of the left pulmonary artery and the left atrial appendage, whereas, in dogs over 35 pounds the shunts were often of insufficient size to carry the load The inside diameter of the aorta and pulmonary artery in dogs of this weight range was from 12 to 20 mm. From these observations it was felt that the optimum ratio of vessel size to shunt size was about 2:1.

Preliminary studies show that the decreased cross-sectional area of the shunts as compared to the pulmonary artery and aorta is reflected in a rise in pressures recorded in the right and left ventricles, especially in larger dogs, after the pulmonary artery and aorta are cross-clamped. In smaller dogs this rise is not so apparent because the shunts more nearly equal the size of the great vessels. The systemic arterial pressure is maintained at adequate levels by this compensatory rise in intraventricular pressure.

DISCUSSION

It is felt that this external shunting procedure affords a simple approach to surgery on the vessels at the base of the heart in which these vessels have to be cross-clamped for varying periods of time. It was originally developed as a by-pass circulation to be used during retransposition of the great vessels in cases of congenital transposition. The feasibility of this approach to the problem of transposition of the great vessels from a purely technical standpoint has been well demonstrated not only in dogs in which it is anatomically easy to cross-anastomose the proximal aorta to the distal pulmonary artery and the proximal pulmonary artery to the distal aorta with the shunts operating, but also in post-mortem dissections of cases of transposition. The physiologic effects of the proposed operation in clinical cases remains to be seen.

In addition, it has been possible to expose the pulmonary valve with a shunt in place carrying the right cardiac output. The pulmonary artery is dissected free to the base of the heart and a curved Potts ductus clamp placed across it in this area carefully avoiding the left coronary artery. A second clamp is placed distally just proximal to the right pulmonary artery. The isolated segment of the main pulmonary trunk can then be opened to expose the pulmonary valve to direct vision, thus suggesting a use in correcting pulmonary valvular stenosis.

With a left-sided shunt in place carrying the systemic circulation it has been possible in dogs to control hemorrhage satisfactorily while approaching the [illegible] valve in a retrograde manner. This same technique might be used in [illegible] aneurysms of the ascending aorta.

Attempts to use the shunts have been made in two cases of transposition of the great vessels in children, one 2½ years old, the other 2½ months, both [illegible] unfortunately the hearts failed before the [illegible]. However, it could be ascertained that adaptation to [illegible] and the insertion was as easy as in the experi[illegible]

SUMMARY

[illegible] devised to by-pass the circulation [illegible] great vessels.

2 The ability of these shunts to carry the entire cardiac output for periods of 30 to 80 minutes has been demonstrated

3 Certain clinical applications of such shunts are suggested

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DISCUSSION

DR T J DONOVAN, Boston, Mass—In 1951 we presented results of over 60 extracardiac shunts from the right ventricle to the distal pulmonary artery It was possible in this series of experiments to ligate the main pulmonary artery and divert the entire cardiac output through this extracardiac shunt from the right ventricle to the distal main pulmonary artery The postoperative duration at that time was a year or more, and these dogs had patent shunts and were healthy and well We now have a three and one half year follow up on these animals, they are still well, as measured by tread mill runs, pressure studies, and other indicator systems The intracardiac portion of the shunt is a plastic tube, and the extracardiac portion an homologous vessel graft ligated to the epicardial end of the tube and sutured end to side to the main pulmonary artery just distal to the ligature The absence of a valve in these shunts seems to cause no significant cardiovascular deficit Apparently the valve in the right ventricular outflow tract is not entirely necessary under these conditions

In the left ventricular shunts, however, a valve is necessary There was presented at that time the use of a lucite ball valve inserted in the apex of the left ventricle to the distal end of which an aortic homograft was affixed and sutured end to side to the descending thoracic aorta With this apical aortic anastomosis and proximal occlusion of the thoracic aorta, the dogs lived for a maximum of six weeks, but the ball valve wore out at that time A new ball valve was designed and, of course, has much better wearing qualities Using this apical aortic anastomosis, it is now possible to divert the entire cardiac output except the coronary circulation through this extracardiac shunt These studies have been done by Dr Stanley J Sarnoff and myself, and will be published shortly

The shunt from the right ventricle to the distal pulmonary artery and the apical aortic anastomosis have relevance to the problems of congenital cardiac cyanosis and aortic valvular disease Since one can provide an avenue of egress from the blocked cardiac chamber, it is possible to correct the surgical defect definitively without the direct approach on the valves to which many cases are refractory

THE CLOSURE OF INTERVENTRICULAR SEPTAL DEFECTS IN DOGS DURING OPEN CARDIOTOMY WITH THE MAINTENANCE OF THE CARDIORESPIRATORY FUNCTIONS BY A PUMP-OXYGENATOR

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THIS communication describes our experience in the closure under direct vision of previously produced high interventricular septal defects with the assistance of an extracorporeal pump-oxygenator circuit.

THE EXTRACORPOREAL APPARATUS

[illegible] of blood about the heart and lungs was accomplished by means of the extra[illegible] oxygenator previously described. Systemic venous blood was withdrawn [illegible] through cannulae placed within the superior and inferior venae cavae, [illegible] returned to the subject through a cannula placed within a [illegible] venous blood was aspirated directly from the open heart and [illegible] chamber from which the blood was pumped to the oxygenator. The [illegible] blood aspirated through a plastic (Tygon) tube introduced in [illegible] through a stab wound at its apex. This tube, which has been previously [illegible] removed any air from the left ventricle and thereby prevented [illegible]. The apparatus was prepared in the manner previously reported. [illegible] taken from donor animals previously heparinized by an [illegible] of 2.5 mg. of heparin per kilogram of body weight. The per[illegible] of the apparatus with regard to hemolysis and maintenance of blood pH and [illegible] determined from Table I.

OPERATIVE TECHNIQUE

[illegible] defects were produced in the manner described by Kay and [illegible] the [illegible] 6 mm. in diameter against the right [illegible] for the procedure was afforded by a left [illegible] which remained [illegible] systolic murmur were [illegible] before repair of the defect was at[illegible] health with one exception. This [illegible] which defects were created with a 12.7 [illegible] [illegible] [illegible] was required to control [illegible] [illegible] the [illegible]

[illegible] to the [illegible]

TABLE I

	BLOOD VALUES IN LATTER PART OF CAVAL OCCLUSION					
DOG NO	HEMATOCRIT (PER CENT)	ARTERIAL BLOOD pH	VENOUS OXYGEN SATURATION (PER CENT)	ARTERIAL OXYGEN SATURATION (PER CENT)	HEMOLYSIS MG HB PER 100 C C PLASMA	TIME CAVAE OCCLUDED (MIN)
0 558	37	7.47	71.7	99.8	49	34
0 559	33	7.30	68.4	101.8	806	29
0 560	43.5	7.35	70.8	97.0	189	28
0 561	33	7.40	72.4	102.6	35	25
0 562	34.5	7.45	81.7	106.0	49	37
0 563	39	7.42	89.8	102.6	51	26
0 564	37	7.24	66.1	94.2	47	26
0 565	35	7.37	77.1	102.4	54	32
0 566	44	7.31	74.2	95.5	110	66
0 567	33	7.41	63.2	104.5	42	29
0 568	46	7.22	38.6	96.2	79	44
0 569	35	7.46	70.8	104.1	57	24
0 570	30	7.27	84.7	103.0	85	29
0 574	45	---	78.4	103.5	189	22
0 577	39	7.34	67.4	101.0	50	33
0 583	39	7.29	76.3	95.5	143	51
0 587	40	7.40	52.0	96.1	85	42
0 588	37	7.30	63.4	96.0	72	74
0 590	44	7.18	68.1	89.1	93	53
0 593	45	7.41	59.1	104.9	110	53
Average	38	7.35	69.7	99.8		38

injections of Pentothal were given as required to maintain a light plane of anesthesia. An endotracheal tube with an inflatable cuff was placed within the trachea and connected to a laboratory type positive and negative pressure respirator. A foreleg vein was cannulated for the introduction of intravenous fluids and drugs.

The right pleural cavity was entered through the periosteal bed of the resected fourth or fifth rib. The superior and inferior venae cavae and the vena azygos major were isolated in preparation for cannulation. Heparin, 2.0 mg per kg of body weight, was then injected intravenously. Both femoral arteries were cannulated centripetally. One of these cannulae led to a mercury manometer where the arterial blood pressure could be observed, the other was employed for the return of oxygenated blood from the extracorporeal apparatus. Curved polyethylene or stainless steel cannulae were attached to the two blood filled tubes leading to the apparatus. One cannula was inserted in a cephalad direction into the superior vena cava through the azygos vein. The pericardium was opened and the other cannula was passed into the inferior vena cava through the tip of the right auricular appendage. Removal of the clamps occluding the tubes leading from the cannulae permitted a portion of the venous return to flow to the extracorporeal apparatus where it was oxygenated and returned to the dog's femoral artery. Ligatures placed about the venae cavae were then tied down on the contained cannulae thus diverting the entire systemic venous return through the apparatus.

The pericardium, which was partially adherent as a result of the earlier operation, was dissected off the heart and the apex was delivered. A stab wound into the myocardium was made immediately posterior to the apex and the 5 mm (O.D.) Tygon vent tube was introduced into the left ventricular cavity through this incision.

A 4 to 5 cm incision was made between stay sutures in the right ventricle. It was made parallel to and within 15 mm of the anterior descending branch of the left coronary artery and it was carried up close to the pulmonary valve. Transected coronary vessels were ligated. Cardiac venous blood was aspirated from the open chamber and returned to the apparatus. The defect was visualized and its size was either measured with calipers in two axes or estimated. The defects were rimmed with a thin band of fibrous tissue which held sutures satisfactorily. Closure of the defect was accomplished [illegible] or plain interrupted sutures of fine silk or cotton [illegible] of the defect, the placing of subsequent su[illegible] with the first suture. The closure was con[illegible]

[illegible] incision was closed with a continuous everting mattress suture which [illegible] The suture was oversewn with a continuous running suture. [illegible] from the left ventricle and this incision was closed with a [illegible] The ligature compressing the vena cava wall about the venous [illegible] permitting the return of systemic venous blood to the right [illegible] the cannulae were then clamped, allowing the heart and [illegible] functions. The cannulae were then removed. An intra[illegible] per kilogram of body weight in a 50 c.c. solu[illegible] approximately a fifteen minute period. Citrated [illegible] required to maintain a normal blood pressure. The thoracic [illegible] layers about a drainage catheter which was removed when sero[illegible] within three hours.

RESULTS

Interventricular septal defects were repaired in the manner described [illegible] twenty dogs (Table II). There were eight operative deaths. One

TABLE II

[illegible]	[illegible]	DURATION OF LIFE AFTER DEFECT REPAIR	CAUSE OF DEATH	DEFECT SIZE AT OPERATION (MM.)	DEFECT SIZE AT AUTOPSY (MM.)
[illegible]	17	68 days	Sacrificed	7 × 9	0
	28	12 hr.	Pulmonary [illegible]	4 × 10	0
	[illegible]	191 days	Sacrificed		2 × 3
	[illegible]	6 hr.	Hemothorax	4 × 10	0
	14	[illegible] days	Sacrificed	[illegible] × 9	0
		118 days	Sacrificed	6 × 10	0
[illegible]	[illegible]	84 days	Sacrificed	7 × 11	0
		[illegible] days	Sacrificed	15 × 17	0
[illegible]	[illegible]	[illegible] days	Fibrillation	10 × 10	0
		[illegible] hr.	[illegible]	10 × 10	0
	[illegible]	7 days	Sacrificed	[illegible] × 9	0
	[illegible]	[illegible] days	Sacrificed		[illegible] × 4
		[illegible] days	Sacrificed	9 × 9	0
[illegible]		[illegible]	Cardiac failure	16 × 16	[illegible]
		[illegible] days	Sacrificed	[illegible] × 6	0
[illegible]	[illegible]	[illegible]	Sacrificed	[illegible] × 4	1 × 1
		[illegible]	Sacrificed	[illegible] × 6	0
	[illegible]	[illegible]	[illegible]	12 × 8	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible] × 1	0
[illegible]		[illegible]	[illegible]	7 × 10	[illegible] × 2
				[illegible] × 6	

[illegible] In this case ventricular fibrillation [illegible] of the left ven[illegible] while the right ventricle was [illegible] reproduced [illegible]

In Dog 588 the defect was immediately under the pulmonary valve A fibrous rim was lacking and many sutures pulled through the septal myocardium before a satisfactory closure could be accomplished by anchoring the sutures rather far from the rim The dog died two hours later as a result of the infundibular pulmonic stenosis thus produced

Three dogs died on the first postoperative day Dog 558 had received a blood transfusion during the creation of the defect thirty-eight days earlier This transfusion was held responsible for the considerable hemolysis in this case (Table I) Post-mortem examination revealed pulmonary edema Dog 574 was in extremely critical condition at the time of operation as has been noted above Death was due to cardiac failure Death in Dog 593 resulted from atelectasis of the entire left lung Enormous gastric distention was also present in this animal Dog 561 died from hemothorax 36 hours postoperatively Post-mortem examination in Dog 567 did not disclose a cause of death Dog 590 died of empyema five days after operation

The remaining 12 animals were sacrificed from one week to six months after operation The hearts were examined with particular attention being paid to the site of the sutured defect and the right and left ventricular incisions

THE DEFECT

The closure was complete in 9 of the 12 sacrificed dogs and 5 of the 8 fatal cases, in one animal only a 1 by 1 mm pinhole remained In four animals defects smaller than 12 sq mm were present at autopsy and in Dog 574 a 6 by 6 mm defect was found at examination on the first postoperative day The margins of the defect had been approximated with three interrupted cotton sutures and the pronounced thrill present before repair was no longer discernible following closure At autopsy, nevertheless, a 6 mm probe could be passed through the sutured defect without disturbing the sutures Probably fibrosis would have partially closed this defect had the dog survived The right ventricular aspect of the sutured defects was represented by a smoothly endothelialized fibrotic area approximating 1 cm in diameter in the sacrificed dogs with three exceptions The heart of Dog 577, sacrificed one week after operation, exhibited multiple friable vegetations in this area, and in two other animals thrombi were found In one a firm thrombus had formed about redundant suture material, but in the other the thrombus was pedunculated and certainly a potential pulmonary embolus

The subvalvular ventricular septum in the canine heart approximates 2 cm in thickness The left ventricular aspect of the closed defect was therefore represented by a dimple the depth of which varied with the degree of fibrosis and the depth to which the closing sutures penetrated the septum In all cases this area was smoothly endothelialized Gross and microscopic views of a sutured defect are shown in Fig 1

THE RIGHT VENTRICULOTOMY

Closure of this incision was satisfactory from both the hemostatic and the healing standpoint In none of the fatal cases did bleeding occur through the incision. In all animals sacrificed two weeks or more after operation the [illegible] was smoothly endothelialized. There were no mural thrombi nor was there significant dilatation of the scar though the fibrotic area was thinner than the surrounding myocardium.

[illegible] View from [illegible] left ventricle [illegible]

[illegible]

on whether the vent tube had penetrated directly into the left ventricular cavity or whether it had tunneled up the anterior papillary muscle en route. The latter course was apt to be followed when the incision was placed on the anterior aspect of the cardiac apex, the papillary muscle being avoided when the vent tube was inserted just posterior to the apex. When the papillary muscle had been penetrated, necrosis developed along the tube's tract in two cases. The endocardium was smooth beneath the apical incision with one exception. In Dog 562 a ball thrombus was precariously adherent to the scar.

SUMMARY

In twenty dogs, previously produced interventricular septal defects were closed under direct vision using an extracorporeal pump oxygenator. There were eight operative deaths. Details of the defect closure and the healing of the cardiac incisions were discussed.

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AN EXPERIMENTAL STUDY OF THE VENOUS COLLATERAL CIRCULATION OF THE LUNG

II. FUNCTIONAL OBSERVATIONS

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IT HAS been observed by several investigators that the venous collateral circulation of the lung may become extensive in certain diseases, especially in emphysema. In 1911 Tiegel constricted the pulmonary veins in dogs and rabbits infected with tuberculosis in an attempt to show that pulmonary tuberculosis was not progressive in a lung which was the seat of chronic passive congestion. Attempts were later made to arrest tuberculosis in man by ligation of the pulmonary veins but with questionable success.[4]

Prior to the use of penicillin, ligation of the pulmonary veins of dogs was usually followed by hemorrhage, pneumonitis, and by thrombosis of veins. Swan and Mulligan successfully ligated the upper lobe veins in dogs but ligation of the veins on one side was fatal in two animals. Hanlon and his coworkers employed penicillin in the early postoperative period and reported reduced mortality after ligation of the pulmonary veins on the right side and diminished incidence of positive blood cultures. They stated that the affected lung became atelectatic and the seat of congestion and hemorrhage in the early postoperative period. After six months the lung was completely aerated but showed evidences of thickening of the alveolar septa. It [illegible] that the lung which re-expands after such venous con[illegible] significant respiratory exchange but is primarily a [illegible] structure. Casts of the bronchial and pulmonary vessels in the present study show, however, that a very large venous collateral circu[illegible]. The purpose of this paper is to report the results of measure[illegible] and oxygen consumption after ligation of the pulmonary veins. [illegible] will be reported separately.

MATERIALS AND METHODS

[illegible] weighing from 10 to 19 kilograms were em[illegible] the first two dogs which had ligations of [illegible] attempt was made to occlude the entire pul[illegible] accomplished on the right side in two dogs. [illegible] and on the left in six. The ligations were done extrapericardially. There were usually three veins to be ligated on the left side and from three to five veins on the right side. All animals received both penicillin (200,000 units) and streptomycin (0.5 Gm.) by the intramuscular route for five days postoperatively.

Bronchospirometry was performed over five minute intervals with the animal anesthetized with alpha-chloralose in doses of 75 to 100 mg. per kilogram. This material provides a light but long-lasting anesthesia with minimal desaturation of the systemic arterial blood (Table I). The modified van Allen cannula that was employed for bronchospirometry has been described elsewhere.[11] The oxygen uptake of each lung was measured with a McKesson double closed-circuit recording spirometer. Changes in midposition of the chest may affect the absolute values of measurements by the closed circuit method, but would not influence the partition of ventilation and of oxygen uptake between the two lungs. The regular straight base line of the bronchospirograms assures that no significant shift of the mediastinum occurs during the measurements.

TABLE I. RESULTS OF GAS ANALYSES OF BLOOD FROM VARIOUS VESSELS IN DOGS WITH LIGATED PULMONARY VEINS

DOG NO.	WT. (KG.)	MONTHS POSTOP.	O_2 CAPACITY (ART. BLOOD) VOL. %	O_2 CONTENT, VOL. %, % SAT. (IN PARENTHESES)				
				FEM. ART.	SUP. CAVA	INF. CAVA	PUL. ART.	VENA AZYGOS
V3	19.1	3	21.09	19.33 (93.5)		14.17 (68.8)	15.54 (75.4)	17.10 (82.9)
V4	17	5	19.83		13.86 (71.5)			14.28 (73.5)
V6	15.4	4	13.90	13.30 (97.3)	10.84 (80.1)	10.61 (78.4)	11.28 (83.4)	13.23 (96.9)
V7	14.5	3	18.57	17.71 (95.4)	12.41 (66.8)		14.93 (80.4)	18.12 (97.6)
V8	12.7	5	21.91	20.71 (95.6)		18.52 (85.7)	18.39 (84.7)	19.43 (89.9)
V9	10.0	5	18.78	17.04 (92.5)		13.68 (74.6)	12.57 (68.5)	15.18 (82.7)
V10	17.7	5	20.42	12.59 (62.9)	9.30 (46.5)	10.24 (51.2)		10.09 (50.6)
V11	Control		18.07	16.29 (91.9)			11.02 (62.5)	12.19 (69.1)
V12	Control		17.29	15.75 (92.9)			11.82 (70.1)	11.40 (67.6)

Catheterization of the venae cavae and azygos veins, right heart, and pulmonary arteries was performed under fluoroscopic control, and the positions of the catheters were recorded on film when there was uncertainty. Pressures were recorded electromanometrically and blood was withdrawn for analysis with the catheter tip in appropriate positions. Blood gas analyses were performed in duplicate with the van Slyke apparatus according to standard methods. No difficulty was encountered in catheterizing the azygos vein. It was merely necessary to direct the bent tip of the catheter posteriorly and to the [illegible] descent [illegible] the superior vena cava. With its entry into [illegible] catheter pursued a characteristic arched posterior course best [illegible]. The azygos blood sample was withdrawn with the tip [illegible] catheter close to the mouth of the vessel and thus proximal to the [illegible] collateral channels from the lung.

OBSERVATIONS

The blood [illegible] (Table I) indicated a remarkably high oxygen con[illegible] in the azygos vein. In most instances it was definitely [illegible] the vena cava or in the pulmonary artery and ap[illegible] the femoral artery and in three instances approximately [illegible]. In Dog V7 where the oxygen content was 0.41 volume per cent [illegible] the azygos vein than in the femoral artery, it is possible that the [illegible] entered or was at the mouth of a huge bronchial vein that was [illegible] the azygos. The data on Dog V10 are difficult to interpret since [illegible] apparently in a state of hypoxia that may have varied in the [illegible] samples. Observations on two normal dogs V11 and V12 [illegible] blood in the azygos vein to have a low oxygen saturation.

TABLE II [illegible] WITH LIGATED [illegible] VEINS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	O UPTAKE CONTROL SIDE	ESTIMATED % [illegible] OPERATED SIDE	% OF EXPECTED UPTAKE LIGATED LUNG
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	18	[illegible]	10	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42.5	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]
							0	
[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	0	20.2
		[illegible]		[illegible]	[illegible]	[illegible]	0	[illegible]

[illegible] bronchospirometric studies (Table II) it is ap[illegible] less altered than circulatory function [illegible]. In [illegible] animal V4 ventilation on [illegible]. In this dog there were no ad[illegible]. Minimal relative ventilation [illegible] V4 [illegible] portion

[illegible] the volume of [illegible] through the [illegible] "effective" flow, from previous experience with the present procedure of bronchospirometry, would stand on the average at 55 per cent for the right side, and 45 per cent for the left. There are considerable deviations from this average in the normal dog which are related to the mobility of the mediastinum.[12] After thoracotomy, moreover, mechanical entrapment of the lung might also interfere with both ventilatory and circulatory function. Nevertheless the stated averages are the most useful available data for present purposes. On this basis the per cent of expected "effective" flow for the operated side is easily calculated from the bronchospirometrically determined oxygen absorption of the two lungs in Dogs V9 and V10 where ligation of the venous drainage has proved to be complete (Table II).

The estimate is more difficult for dogs where the ligation had been incomplete. For this purpose the percentage (Z) of pulmonary parenchyma of which the normal drainage had not been interrupted was estimated by inspection of the casts. The estimate was a generous one in order that falsely high values for collateral flows might not be obtained. The volume of oxygen, the absorption of which was accounted for by lung tissue that had escaped ligature on the operated side, was calculated by applying the percentage Z to the "expected" oxygen uptake for that side. This figure was then subtracted from the observed uptake for that side to yield the oxygen absorbed by the collateral circulation and the latter could then be calculated as a percentage of the "expected" flow, as described in the preceding paragraph. From the data summarized in the last column of Table II, "the effective collateral flow" after an interval of three to five months tends to range between approximately eight and 20 per cent of that expected were the venous drainage intact, with one questionable value (Dog V10) as high as 61.7 per cent.

The data were sufficiently complete for the calculation of effective blood flow on the side of a complete pulmonary venous ligation in only one dog of the present series, V9. For the calculation the Fick formula was modified by using the observed oxygen capacity, rather than oxygen content of the systemic arterial blood. In this dog the effective flows through the normal and ligated lung amounted to 1288 and 129 ml. per minute, respectively.

It is obvious that the part of the right cardiac output passing through the segments of the lung in which venous outflow was ligated is returned to the right heart and that only the blood passing through the normal lung is directly turned over to the left heart and to the systemic arterial circulation.

Another calculation can be used to estimate the collateral circulation that drains through the azygos vein. The blood in the pulmonary artery may be regarded as a mixture of the azygos blood and of the venous blood of the systemic circulation. In Dog V6 the data permit that an arithmetic mean be taken of the oxygen content of the blood in the inferior vena cava (10.61 volumes per cent) and of that in the superior vena cava above the azygos (10.84 volumes per cent). This mean oxygen content of 10.73 volumes per cent is considered as representing that of the total mixed venous blood ex-

[illegible] the azygos. To obtain an oxygen content in the pulmonary artery of 11.2[illegible] volumes per cent, as determined, 78 parts per cent of this blood must [illegible] mixed with 22 parts per cent of azygos blood (oxygen content 13.23 volumes per cent). Even this estimate of relative flow is too low, since the [illegible] content of the coronary venous blood is generally lower than that of the caval blood. Moreover, it is apparent from the anatomical studies that [illegible] the blood flowing through the collateral circulation enters the venae [illegible] especially the superior through other channels than the azygos.

DISCUSSION

There was no mortality associated with ligation of the major veins of the lung in ten dogs. The use of penicillin and streptomycin in the early post-operative period probably played a major role in the survival of these animals and in the abolition of the inflammatory factor. Only two dogs had mild [illegible] hemoptysis. None showed any evidence of thrombosis. There was [illegible] ordinary enlargement of pre-existing bronchial veins at the hilum [illegible] as well as the development of new transpleural hilar and terminal veins. These [illegible] could be traced into large systemic veins, chiefly the pericardiophrenic and intercostal veins. The extensive collateral circulation in the affected lungs is capable of transporting oxygen to the systemic veins and eventually to the right heart. The evidence for this statement is based on the [illegible] oxygen uptake and on the elevated content of oxygen in the [illegible] approached the oxygen saturation level of arterial blood. The [illegible] this procedure to patients with congenital transposition of [illegible] itself. The success of such a procedure would de[illegible] and rapidity of development of collateral circulation and [illegible] of the human heart to adapt itself to the additional burden [illegible] side by the shunt.

SUMMARY

[illegible] the right lung in two dogs and of the left lung [illegible] without mortality. The use of streptomycin with [illegible] in preventing infection.

[illegible] collateral circulation was observed. This circulation con[illegible] pre-existing bronchial veins [illegible] pleural adhesions [illegible] three and five months [illegible] between [illegible] 20 per [illegible] The oxygen content [illegible]

[illegible]

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PHYSIOLOGIC BASIS FOR UTILIZATION OF ESOPHAGOCARDIOMYOTOMY IN THE TREATMENT OF ACHALASIA

Paul Nemir, Jr., M.D. (by invitation) and H. R. Hawthorne, M.D.
(by invitation)
Philadelphia, Pa.

IN THE early part of 1948, being dissatisfied with the poor results which we had obtained with the methods of surgical treatment currently employed [illegible] achalasia of the esophagus, we began to use the modified Heller procedure or esophagocardiomyotomy. The early results in the first few cases [illegible] encouraging that we began routinely employing this operation in all patients submitted to surgery for intractable achalasia.

This procedure has been carried out on 25 patients up to the time of this report. One of the patients died of a cardiovascular accident on the fifth [illegible] day. The remaining 24 are available for follow-up study of from [illegible] months to [illegible] six years.

All of the 24 patients were relieved of their symptoms of dysphagia following operation. Excellent results were obtained in 21 (86 per cent) of the [illegible] in that they have had complete relief from the obstruction [illegible] full diet. Subsequent dilatations have not been [illegible] this group of patients. Three of the patients had post[illegible] in the form of delayed gastric emptying, regurgitation [illegible]. They have been alluded to previously in [illegible]

[illegible] group with those in which more formidable procedures [illegible] esophagogastrostomy or partial resection of the esoph[illegible] clear that the results with the relatively simpler pro[illegible] are unequivocally better than those ob[illegible]. While we have continued to have complete [illegible] required less exte[illegible]

[illegible]

We, therefore, undertook studies in the hope of clarifying some aspects of the problem

1 Why has the purely local procedure of esophagocardiomyotomy been so effective in a disease involving the entire esophagus?

2 Why have there been fewer complications?

3 What information can we add to the controversial question of etiology?

This report is concerned with esophageal motility studies on patients having achalasia on whom esophagocardiomyotomy was performed In addition, special fluoroscopic observations have been made Fifteen patients having achalasia have been studied We have also studied motility patterns in three patients with normal esophagi and in three patients having carcinoma of the lower esophagus

METHODS

Studies were made both preoperatively and at varying intervals up to two years postoperatively With the patient in the fasting state a triple lumen, triple ballooned tube (Fig 1) is passed into the stomach under fluoroscopic guidance Obviously in a number of the preoperative studies this has been at times very difficult Almost invariably, however, successful passage of the tube could be accomplished by the administration of Seidlitz powders once the tip of the tube had been in position in the lowermost portion of the esophagus Actually it has been our experience that if the obstructed area in the region of the esophagogastric *junction cannot be traversed by the tube with* the addition of Seidlitz powders then it is highly probable that the obstruction

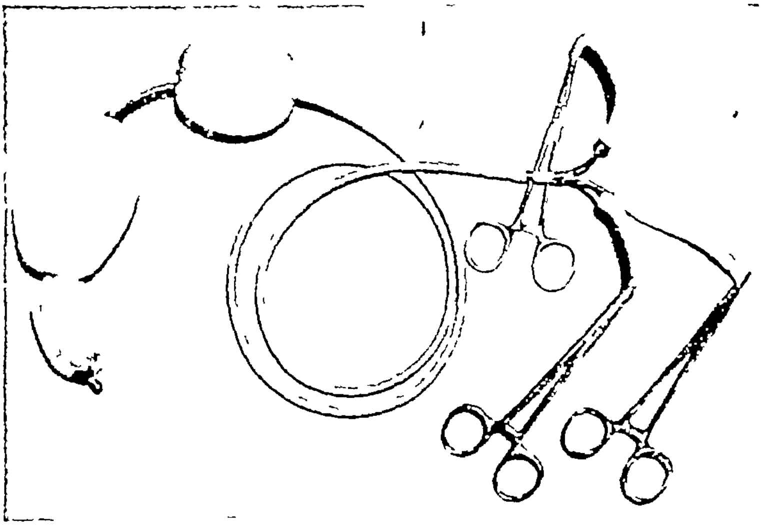
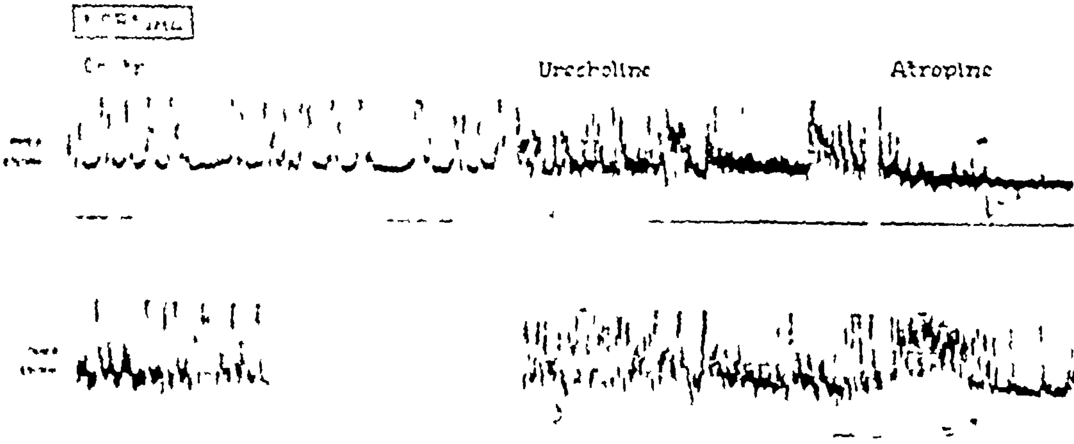


Fig 1 —Triple lumen triple balloon tube used in recording esophageal motility Usually each balloon was filled with 20 to 30 c.c. of air However in some of the markedly dilated esophagi as much as six times this amount was needed before phasic contractions could be recorded The lower balloon is placed into the cardiac portion of the stomach the middle balloon in the esophagogastric junction and the upper balloon in the upper or mid esophagus

[illegible] the basis of achalasia. Postoperatively the passage of the tube was [illegible] accomplished with less difficulty than preoperatively. The lower-[illegible] balloon is inflated in the stomach, the tube is pulled back and the second balloon is inflated in the esophagogastric junction. The third balloon is [illegible] the junction of the upper and middle thirds of the esophagus. The balloons are then connected through a strain gauge and Lilly Capacitance manometer to a Polyviso four channel electromanometer and esophageal contractions at the esophagogastric junction and in the upper esophagus are recorded on Permapaper. We have realized the difficulties inherent on using these [illegible] balloons for the motility studies[3] but have felt that the errors incident to the size of the balloons would be more than compensated for by the extreme sensitivity of the recording apparatus as opposed to the tambour arrangement. Following control tracings various drugs have been used—thus far, namely, Urecholine, atropine and procaine.



[illegible]

[illegible] to determine whether regurgitation was [illegible] The patient was given a barium swallow and [illegible] placed in the Tren[illegible] [illegible]

RESULTS

Fig 2 shows the esophageal contractions of the normal esophagus for comparison Note the rhythmic contractions, the amplitude and frequency of contractions, and the resting tone The pressure plateau of the symmetrical wave attains a peak pressure of 80 to 100 mm Hg Approximately 10 minutes following the subcutaneous administration of 5 mg of Urecholine, the frequency and amplitude of contractions markedly increased as might be anticipated This effect was dissipated in around 10 to 20 minutes Approximately 20 minutes following the administration of 0 6 mg atropine sulfate the contractions became markedly diminished or ceased entirely for a period of around 10 to 15 minutes, at which time the effect of the atropine was apparently dissipated

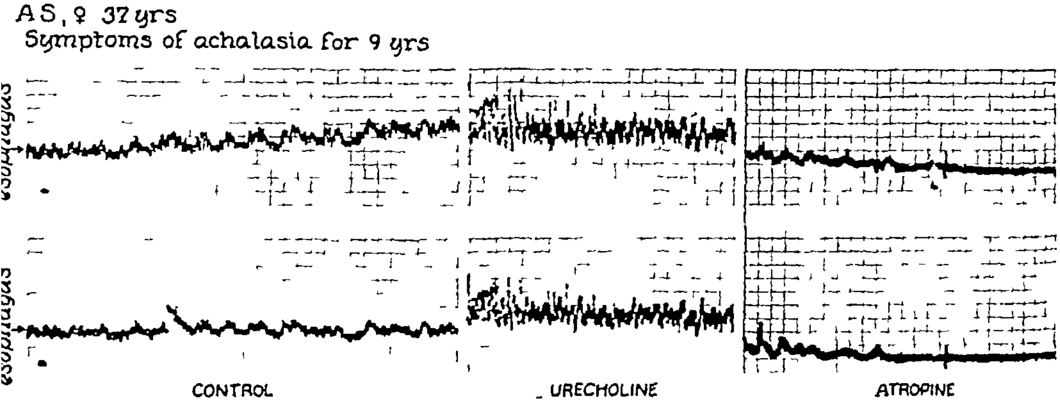


Fig 3 —Esophageal motility pattern in a 37-year old woman with symptoms of achalasia for 9 years Tracing speed and pressure range same as in Fig 2 Note the lack of rhythm the decreased amplitude and frequency of phasic contractions and the variable tone in the control tracing Upper balloon inflated with 70 c.c air and esophagogastric junction balloon inflated with 30 c.c of air The second block was taken ten minutes after Urecholine (5 mg subcutaneously) and the third block fifteen minutes after 0 6 mg atropine sulfate

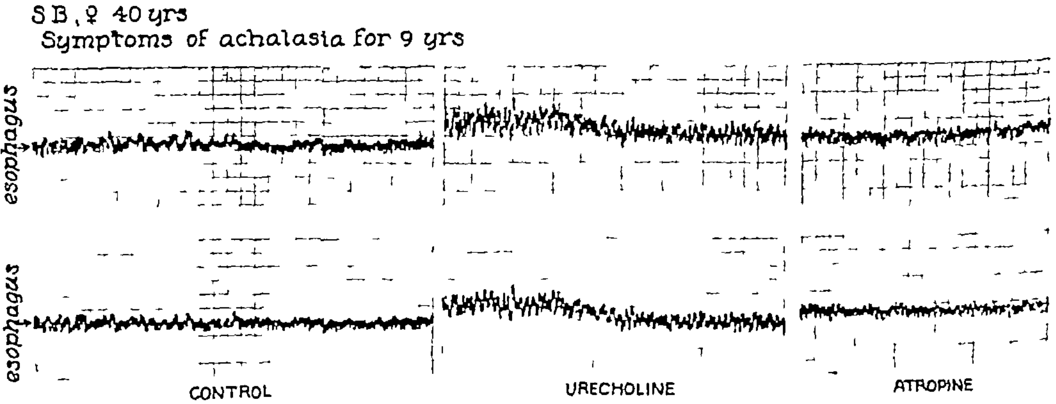
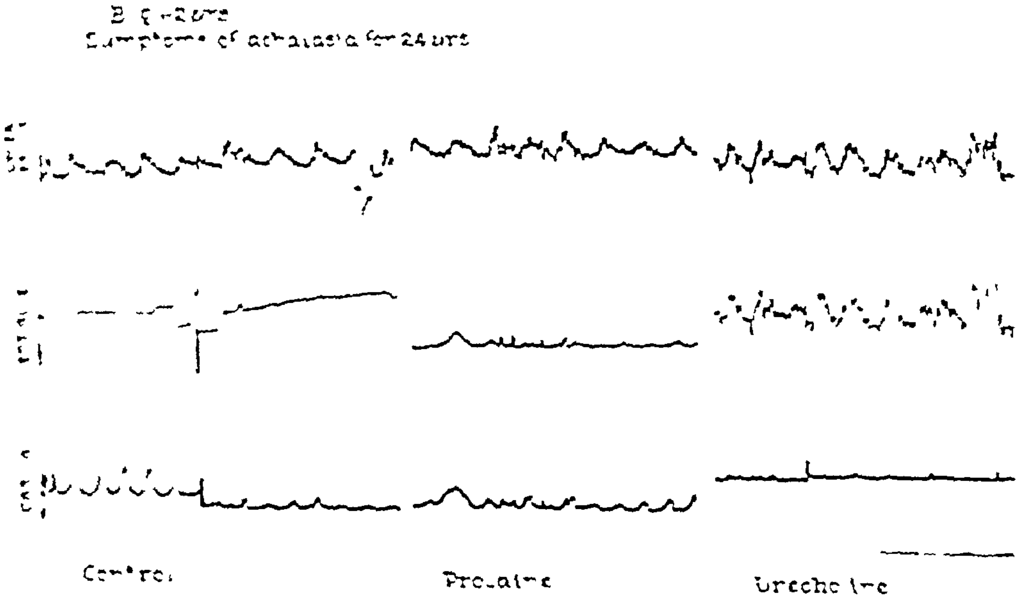
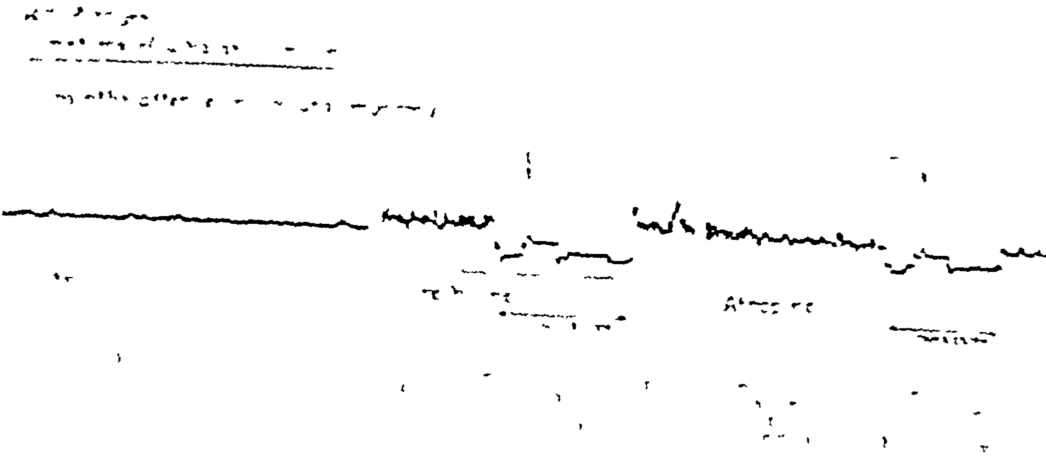


Fig 4 —Esophageal motility pattern in a 40 year old woman with symptoms of achalasia for nine years Note that the phasic contractions are markedly decreased in amplitude and totally unrhythmical

[illegible] the tracings on the patients with cardiospasm, representative [illegible] shown in Figs. 3 to 6, reveals the following:

1. The [illegible] the entire esophagus is altered in cardiospasm [illegible]. Note the marked difference of the upper eso[illegible] with cardiospasm (A. S., Fig. [illegible], and S. B. [illegible]) [illegible] normal (Fig. 2).





3 The resting tone of the dilated esophagus was usually approximately the same, or higher, than in normal tracings It should be here mentioned, however, that in the patients with achalasia, greater inflation of the balloon as compared to the normal was invariably required before any phasic contractions at all could be obtained In the patients with widely dilated esophagi, it was sometimes necessary to distend the upper balloon with as much as 150 to 200 c c of air before any contractions were noted

4 An increase in the resting tone was frequently, though not invariably, recorded in the tracing from the balloon at the esophagogastric junction area or vestibule[8] Fig 5 shows a striking example of this response

5 The response to Urecholine and atropine in the patient with cardiospasm has been in the same direction as in the normal With Urecholine, the amplitude and frequency of contractions increased, although never to the same magnitude as seen in the normal esophagus

6 There is no relationship of proportionality between length of time of existence of the condition and degree of motor abnormality Fig 6 shows the tracings on a 20 year-old white man upon whom an esophagocardiomyotomy had been performed elsewhere* approximately one year before study This patient's symptoms were of only one year's duration prior to operation whereas the vast majority of the patients studied had symptoms anywhere from 5 to 30 years The most marked decrease of tone, and frequency and amplitude of phasic contractions of any patient studied was obtained

7 Studies taken from 4 months to 2 years postoperatively have revealed no change of the original altered motility pattern Careful analysis of the pre and postoperative tracings showed little or no difference In several of the postoperative tracings, the amplitude of contractions was slightly increased but this finding was not consistent and varied with the amounts of air employed to inflate the balloons

8 Fluoroscopic study at the time of barium swallow has demonstrated the presence of regurgitation from the stomach into the esophagus in 50 per cent of the patients postoperatively Usually this has been a very rapid and free regurgitation with the patient in the Trendelenburg position (Fig 7)

DISCUSSION

As stated, our results clearly demonstrate the superiority of esophagocardiomyotomy over previously used surgical procedures in that segment of patients with cardiospasm who are candidates for surgery It is equally apparent however, that complications of a severe nature continue to occur postoperatively, thus indicating that this procedure is by no means the final answer to the problem As stated the manner in which esophagocardiomyotomy exerts its beneficial effect is not entirely clear In our own studies and those of others[5 9] it has been clearly demonstrated that the motility pattern of the entire esophagus is disturbed in achalasia To be sure, the more severe changes are usually present in the lower esophagus but it is a function of degree

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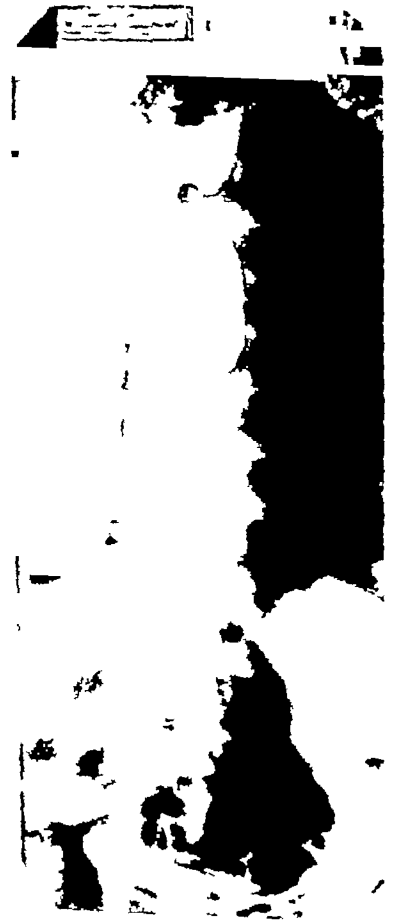
*This patient was operated upon by Dr Richard H Sweet, Boston Mass [illegible] motility patterns are disturbed throughout the esophagus and since [illegible] is noted in esophageal motility patterns postoperatively, it must be concluded that the alteration is wrought entirely locally at the site of the operative procedure.

There is no unanimity of opinion as to the causative mechanism for the obstruction at the lower esophagus in cardiospasm. While it has been generally held that the obstruction was on the basis of a spasm of the inferior [illegible] constrictors, other investigators have felt that it may be due to



[illegible]

[illegible] normal [illegible] While it [illegible] that the refractory period of the smooth muscle of the frog's rectum is reduced from seconds to milliseconds when freed from its associated ganglion cells. Reduction of refractory period would facilitate the development of the circus movement of excitatory impulses with resulting tetanic contraction and functional obstruction.[11] The esophagocardiomyotomy with its resulting scar might thus act as a barrier to circus movement. This hypothesis might be applicable to those cases of achalasia in which Auerbach's plexus is absent, but, contrary to general opinion,[12, 13] the plexus is not invariably absent. On the other hand, however, while Auerbach's plexus may be present microscopically, it may not be working as a normally functioning unit and it may be that the above-stated hypothesis may even be acting in this group. Evidence for

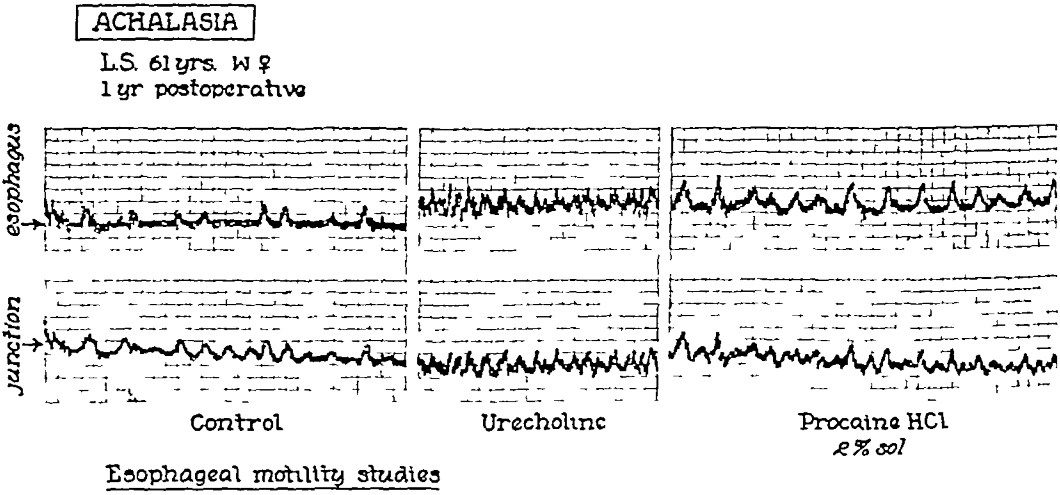


Fig. 8.—Esophageal motility pattern of a 61-year-old white woman who had an esophagocardiomyotomy for achalasia one year prior to study. Note the alteration of the pattern toward normal following the oral administration of 30 c.c. of 2 per cent procaine hydrochloride. This effect was almost immediate and lasted for approximately 20 minutes.

alteration of the functioning intrinsic nervous mechanism of the esophagus in patients with achalasia was afforded by our own studies utilizing oral procaine. It was shown that after swallowing 30 c.c. of 2 per cent procaine solution the esophageal contractions in three postoperative patients changed from the usual abnormal pattern (characterized by decreased amplitude, decreased frequency, and total lack of rhythm of contractions) to an essentially normal motility pattern (characterized by greater amplitude, greater frequency, and rhythmical contractions) (Fig. 8).

Since it is known that procaine may be absorbed locally from a mucosal surface, it may be that it has inactivated the altered intrinsic neural mechanism and the vagus is then able to exert its normal effort.

Sleisinger, Steinberg, and Almy[9] have also postulated that the intrinsic neural mechanism may not be totally lacking but rather that it is disorganized

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DISCUSSION

DR R E TABER, Iowa City, Iowa —I should like to comment on the paper by Dr Nemir regarding esophageal motility, and tell of utilizing a similar method of examination

We have attained different results and I thought they might be of interest to you This is a preoperative slide, here are three balloons recording at the upper third, middle, and lower thirds just above the cardiac sphincter Here are the results and return of motility so far as we can tell to a normal pattern some 15 months following cardioesophageal myotomy

Here is a summary of three more patients with far advanced cardiospasm These are the preoperative tracings and this is the postoperative study carried on at varying intervals between three months and one year following operation I think you can see that there is a return to near normal motility in these patients who beforehand demonstrated long periods without any contractions

We believe the causative factors lie in the cardiac sphincter mechanism, rather than in the esophageal myenteric plexus changes which are more likely secondary to chronic obstruction and stasis

DR ORVILLE F GRIMES, San Francisco, Calif —A little over a year ago a study was undertaken by Dr Stephens and myself in an effort to determine the comparative values of the various surgical procedures for achalasia of the esophagus performed at the University of California Hospital

Until 1948 the procedures used were those whereby some type of plastic repair was accomplished on the cardioesophageal junction In 26 patients, an anastomosis was established between the lower end of the esophagus and the cardiac portion of the stomach, patterned after the Finney pyloroplasty A Mikulicz procedure was accomplished on four other patients, and a manual dilatation was performed in one

Since 1948 all patients who have required operation for intractable achalasia of the esophagus have received the so called extramucous cardioesophagomyotomy The incision has been carried from the level of the inferior pulmonary vein well down onto the anterior surface of the cardia of the stomach and in most instances the diaphragm has been opened

A study of the operative results obtained from the so called enterostomy procedures the patients having been followed for a considerable time, shows that well over 50 per cent of the patients had either fair or poor results By comparison, the Heller procedure performed in eleven patients, produced results that were uniformly good or excellent

It is of interest to note that a considerable number of patients in the enterostomy group developed postoperative esophagitis This complication did not occur in those receiving the Heller procedure

It is our impression that the good results of the extramucous cardioesophagomyotomy are due not only to the increase produced in the cross sectional diameter of the esophagus in its narrowed portion, but also to the preservation of the cardioesophageal angle

DR I DARIN PUPPEL, Columbus, Ohio —We recorded the first successful esophageal motility study, which we did in 1947 * Since 1947 we have investigated thirteen cases of idiopathic megaesophagus, 11 cases both preoperatively and after singly and widely cutting across the so called cardiac sphincter by "U" esophagogastrostomy or by cardiomyotomy We have used the single or the multiple balloon technique concomitantly as described by Dr Nemir, and which I presented before this Association in a discussion of Dr Kay's paper in 1952 † Much of our data has already been confirmed by Kramer and Inglefinger

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*J Thoracic Surg 25 13 1953
†J Thoracic Surg 25 13 1953

The balloon methods do have their shortcomings. First, they do not record the [illegible] because in megaesophagus localized contractures of the esophagus may [illegible] simultaneously in multiple areas at various levels of the esophagus. Second, the balloon methods do not record the force of deglutition. Third, the balloon methods do not [illegible] the esophageal respirations and pulsations. We had to use the fluoroscopic technique particularly in the upright and Trendelenburg positions to determine the state of peristalsis. We determined the force of deglutition by observing the amount of pull on the [illegible] tube attached to the inflated balloons which acted as boli of food. We differentiated the esophageal respirations and pulsations from the intrinsic motility by using the breath holding technique and recording the radial pulse frequently. In achalasia there was [illegible] voluntary need to swallow over normal and each conscious swallow was [illegible] the kymograph by the patient pressing a signal magnet. The balloon methods have had their positive value. Just as a positive tuberculosis sputum culture increases the [illegible] in reviewing chest roentgenograms and we see the formerly unseen cavity, so [illegible] have increased our insight as to the abnormalities we see at fluoroscopy [illegible] reading esophagograms.

Idiopathic megaesophagus does not act like the atropinized esophagus of normal people. It cannot be stimulated to normal peristalsis and normal deglutition by administration of Urecholine as we pointed out in 1952. Drugs like Urecholine may often stimulate to an increased motility and may thus be of diagnostic aid to the fluoroscopist because the motility still remains uncoordinated and nonperistaltic in nature. Usually Urecholine administration leads to little or no increase in deglutition.

The observations of Dr. Nemir and ourselves do agree with each other. In our ex[illegible] the disturbances of the esophageal motility continue after cutting the so-called cardiac sphincter once widely. Of our 13 patients the patient observed longest had the operation in 1946; she still shows the typical esophageal motility disturbances of idiopathic megaesophagus in spite of excellent clinical amelioration of symptoms. Of [illegible] complete tragedy to have one's pioneer observations questioned. I have [illegible]. But when one confirms another's observations as much as Dr. Nemir [illegible] Dr. Hawthorne have confirmed mine, it is always a source of great satisfaction. They [illegible] for their fine work. In 1952 we suggested that the present mod[illegible] [illegible] the abnormal physiology and that other better concepts will [illegible]. Dr. Nemir and Dr. Hawthorne are doing just that in their studies of [illegible] on the esophagus. More studies in such directions should be done.

It is [illegible] that Dr. Faber is not recording increased intrinsic esophageal [illegible] but is rather recording respiratory movements differently. We [illegible] interpretation when we first began our esophageal motility work. [illegible] to reveal the intrinsic motility irregular, uncoordinated, hyporesponsive [illegible] in nature and at times even absent both preoperatively and post[illegible]

[illegible] that the cricopharyngeal sphinc[illegible] [illegible]. This is fortunate for [illegible] incompetent cardiac sphincter. I wish to [illegible] the cricopharyngeal [illegible] not become [illegible]

[illegible] have their disadvantages, complications and [illegible] that the patient should not [illegible] we do a cardiomyotomy in the presence of hyperchlorhydria or euchlorhydria and an esophagogastrostomy if there exists an associated hypochlorhydria or achlorhydria A Levin tube can easily be passed into the stomach to collect gastric juices, provided the upright patient inhales amyl nitrite at the time a new stiff tube is passed under fluoroscopic guidance

DR PAUL NEMIR, Jr (Closing) —I wish to thank the discussants for their comments Dr Taber's results with Urecholine are interesting We have studied more than fifteen patients both preoperatively and up to two years postoperatively, and in no case have we demonstrated any appreciable increase in the tone of the esophagus or any increase in its contractile ability following operation Esophageal motility and contractility postoperatively, following Urecholine administration, was essentially no different from that obtained preoperatively Fluoroscopically, the continued loss of tone has also been noted, although, in all cases postoperatively, esophageal emptying has been markedly improved In several cases the size of the esophagus was decreased following operation, but in none did the motility pattern assume a normal configuration Our results with esophagocardiomyotomy and with the other procedures have paralleled the results which Dr Grimes has shown Eighty six per cent of the patients upon whom we operated have been relieved of their symptoms of achalasia and are, without exception, able to take a full diet Subsequent dilatations have been required in no case

I want to thank Dr Puppel for his comments I hasten to add that his original studies in this field of investigation served in a large part as the stimulus for our work

we do a cardiomyotomy in the presence of hyperchlorhydria or euchlorhydria and an esophagogastrostomy if there exists an associated hypochlorhydria or achlorhydria A Levin tube can easily be passed into the stomach to collect gastric juices, provided the upright patient inhales amyl nitrite at the time a new stiff tube is passed under fluoroscopic guidance

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THE EFFECT OF INTRAPERICARDIAL AND INTRACARDIAC PROCAINE UPON THE CIRCULATION IN MAN DURING MITRAL COMMISSUROTOMY AND PULMONARY VALVULOTOMY

Hugh F. Fitzpatrick, M.D. (by invitation), E. M. Papper, M.D., Enzo Krahl, M.D. (by invitation), F. F. McAllister, M.D. (by invitation), and
George H. Humphreys II, M.D.
New York, N. Y.

Among the important problems associated with operations upon the heart and great vessels are disorders of cardiac rate and rhythm. Two common causes of these disturbances are surgical manipulation of the heart and the direct effect of anesthetic procedures. Many of these arrhythmias are of clinical concern because of the possibility of producing ventricular tachycardia and in turn fatal ventricular fibrillation. Another important unfavorable possibility associated with these changes in rhythm is the alteration in perfusion pressure of vital organs, including the heart itself. This occurs if the central arterial pressure is reduced because of a fall in cardiac output resulting from an abnormal rate or rhythm, making cardiac filling or emptying inefficient.

Attempts to resolve the real and potential danger of serious arrhythmias during the manipulations on the heart and surrounding structures have taken two forms. One has been an effort to depress bursts of ventricular arrhythmia by systemic use of drugs which depress the conducting tissue of the heart. Possibly the most popular of these efforts to control arrhythmias *in man* was the use of procaine or its derivative procaine amide intravenously. The efficacy of procaine in the control of arrhythmias associated with anesthesia and with surgical manipulations including those upon the heart was reported by Burstein and his associates in a series of communications beginning in 1940.[1-3] However, the usefulness of systemic procaine was limited by its short duration of action, the need for general anesthesia to avoid convulsions, and restriction to the intravenous route. To surmount these difficulties, procaine amide was developed and studied by Mark[4] and Joseph[5] and their co-workers. The latter group demonstrated efficient protection against arrhythmias in a variety of thoracic surgical procedures with the use of procaine amide orally and intravenously.

The other and earlier effort at prevention and control of arrhythmias resulting from manipulations upon the heart and great vessels consisted of the direct application of procaine as a local anesthetic agent to the projected area

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of stimulation. As described by Mautz[6] and Beck,[7] 5 or 10 per cent procaine hydrochloride was used by application of sponges saturated with procaine to the epicardium. It was suggested by Mautz[6] that the drug was absorbed through the epicardium and depressed irritability in the underlying myocardium. Reports were satisfactory with respect to the subsequent control of irregularities of rhythm. Apparently, no difficulties due to systemic absorption were encountered. Procaine injected either locally or intravenously has actions other than those of combating arrhythmias by myocardial depression. It is also a fairly efficient peripheral vasodilator. Therefore the question is raised whether these qualities in a drug might not pose problems in the circulation of even greater magnitude than those they were designed to correct. It is necessary to know whether a reduction in arterial pressure resulting from direct myocardial depression or peripheral vasodilatation or both, in patients whose hearts are already damaged, may not be a much more severe liability than the development of short bursts of irregularities of rhythm.

In the course of study upon the relationship of anesthetic agents and methods to circulatory changes induced by the surgical correction of certain types of congenital and acquired heart diseases,[8] an opportunity occurred to carry on objective and quantitative measurements upon the circulation following the intrapericardial and intracardiac injection of procaine for the prevention of arrhythmias.

METHODS

Electrocardiograms were made (Lead II) simultaneously with the recording of arterial pressure with Lilly Capacitance Manometers at appropriate periods during operations on the mitral or pulmonary valves.

A total of 50 patients were studied. Of these, 31 patients were observed immediately before, during, and after the injection of procaine into the pericardium or into the heart muscle. Tracings were made continuously until it was evident either that no change was going to occur or that a change that had occurred had begun to revert toward normal. Eleven patients were studied during mitral commissurotomy and 20 patients during pulmonary valvulotomy for pulmonic stenosis. Similar studies served as control measurements in 19 patients. In 16 (12 mitral commissurotomies and 4 pulmonary valvulotomies) operation was carried out without any injection of fluid. Physiological (0.85 per cent) saline was injected into the pericardial sac in 3 patients to determine the influence of fluid injection without active drug on cardiac rhythm and rate. The data obtained in these 3 patients were similar to the observations in those 16 patients who received no injection.

Preanesthetic medication consisted of an opiate or synthetic narcotic and scopolamine or atropine. The most common premedication was a combination of meperidine and scopolamine. Anesthesia for maintenance consisted of either ethylene or nitrous oxide and small amounts of ether. Endotracheal intubation was performed on all patients. The endotracheal tube was inserted during topical anesthesia in most adult patients and during general anesthesia in all children. When procaine was injected into the pericardium or myocardium, the amounts varied from 1 to 10 c.c. of 1 or 2 per cent solution.

RESULTS

Table I demonstrates the findings in 11 patients in whom procaine was injected into the pericardial sac and at the base of the auricular appendage prior to mitral commissurotomy. There was a significant increase in heart rate in 8 and a fall in blood pressure in 4 of the eleven There was one instance of cardiac arrest (Patient G M.) during the initial manipulation which was corrected by cardiac massage Although the patient regained lucid consciousness and suffered no postoperative impairment of renal function she died on the eighth postoperative day of congestive failure This patient also had severe aortic valvular disease at autopsy There was one instance of ventricular fibrillation (Patient H H.) in the first mitral commissurotomy performed in this hospital The fibrillation was reversed after cardiac massage and intracardiac procaine Death ensued in congestive failure on the seventh postoperative day in a manner similar to that of Patient G M In every operation there were short bursts of ventricular extrasystoles at the actual moment of finger fracture of the commissures

TABLE I. MITRAL COMMISSUROTOMY PROCAINE

PATIENT	BEFORE PROCAINE		AFTER PROCAINE†	
	BP ‡	PR §	BP ‡	PR §
E C	90/68	80	90/68	105
M. D *	92/54	135	68/40	160
M. R *	115/74	70	115/74	85
F T *	80/48	85	72/48	130
V H *	124/70	60	84/46	100
M. M *	120/80	76	130/75	80
G M.*‖	110/65	110	100/60	120
T R *	78/38	58	74/40	110
G S *	135/75	70	110/60	110
H H.*¶	Not obtainable	140	Not obtainable	200
M. B *	110/70	90	110/70	100

*Preoperative digitalization

†Maximum change two minutes or less after the injection of procaine.

‡Blood pressure

§Pulse rate.

Cardiac arrest during mitral manipulation Died eighth postoperative day of congestive heart failure.

¶Ventricular fibrillation reversed with procaine and cardiac massage. Died seventh day of congestive failure.

Summary

Pulse		*Blood Pressure*	
Total	11	Total	11
Tachycardia	8	Hypotension	4
No change	2	No change	7
Cardiac arrest	1		

TABLE II MITRAL COMMISSUROTOMY NO PROCAINE USED DURING HEART MANIPULATION

PATIENT	BP †	PR ‡
C F *	124/66	75 78
D W *	110/50	60
W D *	100/60	70 76
R D *	110/70	76
B D *	116/80	80 84
A L.*	116/70	76 80
C C *	110/70	80 84
A McC *	112/70	60 65
W McF *	100/60	76 80
C U *	110/76	80
J A.*	100/60	90
J M *	105/65	75

Preoperative digitalization.

†Blood pressure

‡Pulse rate

In contrast to this experience, 12 patients with comparable types of mitral valvular disease received no procaine Table II summarizes the data measured continuously during the surgical manipulations There were inconsequential changes in heart rate and blood pressure There occurred the same bursts of ventricular extrasystole of approximately the same duration as were found in the patients who were given procaine

TABLE III. PULMONARY VALVULOTOMY PROCAINE

PATIENT	BEFORE PROCAINE		AFTER PROCAINE*	
	BP †	PR ‡	BP †	PR ‡
J R	110/70	90	95/70	125
W F	95/50	95	100/50	155
R S	140/90	100	95/65	140
L G	110/60	82	110/60	148
C M	85/45	160	60/40	185
A S	100/65	82	100/65	120
B C	70/40	120	70/40	150
S C §	106/60	100	100/60	140
T M.	156/84	118	130/80	152
R E	118/50	100	115/60	165
D P	130/75	90	110/72	130
T B	120/70	92	116/80	160
B K	134/50	120	114/46	138
J A	120/60	150	74/50	190
L C	136/82	120	125/82	162
G T	120/76	120	76/46	150
L R	132/80	105	114/70	176
C R	120/80	88	120/80	165
J K	100/55	95	100/55	140
J B	82/52	115	82/52	140

*Maximum change two minutes or less after the injection of procaine

†Blood pressure.

‡Pulse rate

§Cardiac arrest interventricular septal defect dilators inserted through defect into aorta

Summary

Pulse		*Blood Pressure*	
Total	20	Total	20
Tachycardia	20	Hypotension	10
No change	0	No change	10

The same contrast is evident in comparing 20 cases of pulmonary valvulotomy in which procaine was used with 7 in which either saline or no injection took place This is shown in Tables III and IV Tachycardia occurred in every case in which procaine was used and in half it was accompanied by a

TABLE IV PULMONARY VALVULOTOMY

PATIENT	BP †	PR ‡
A No Procaine During Heart Manipulation		
A S	126/60	92
R S	85/40	80
M B	120/60	95
I D	122/68	120
B Saline in Pericardium During Heart Manipulation		
H T *	110/58	70
T O	120/60	90
M C	100/60	90

Preoperative digitalization

†Blood pressure

‡Pulse rate

fall in arterial pressure Again there was no difference in the incidence or severity of the ventricular extrasystoles whether or not procaine had been used In fact, the only patient who exhibited no extrasystoles at all was M G in Table IV, B This patient received a saline intrapericardial and intraventricular injection Figs 1, 2, and 3 are taken from actual recordings which illustrate the points discussed

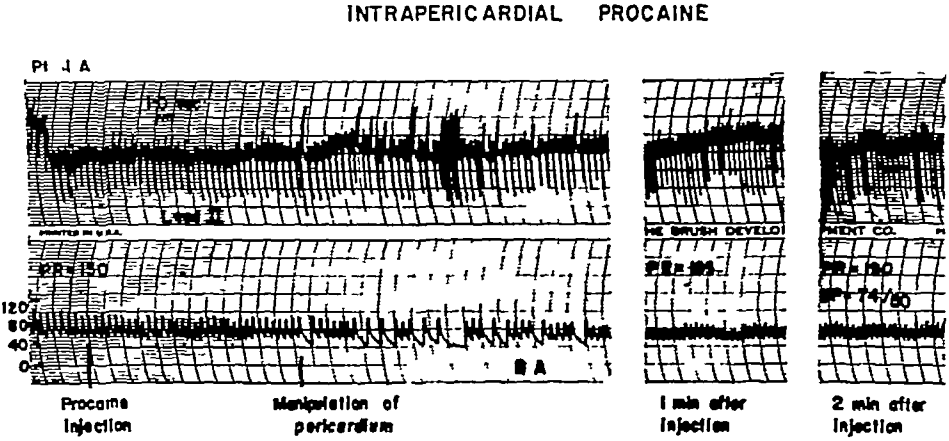

Fig 1—A fall in brachial artery pressure and an increase in heart rate occur after the injection of 4 c.c. of 1 per cent procaine into the pericardium. Multiple extrasystoles are seen during pericardial manipulation Alterations one and two minutes following injection are also shown.

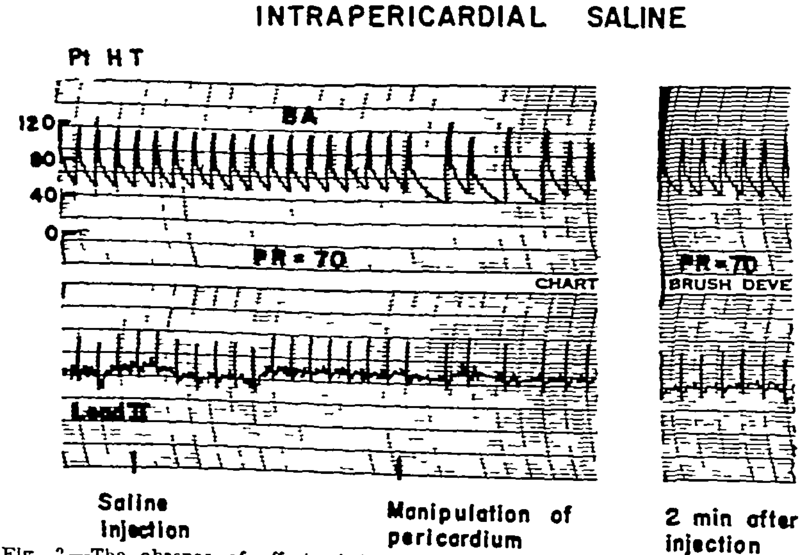

Fig 2—The absence of effect of intrapericardial saline injection is shown. Extrasystoles occur during surgical manipulation but no alteration in blood pressure or pulse rate is noted

DISCUSSION

It is necessary to emphasize that no inference is made from these data that ventricular tachycardia and ventricular fibrillation do not and cannot occur during operations upon the heart or great vessels Ventricular tachycardia was not observed in this relatively small but well-measured series. Ventricular fibrillation was seen once and apparently responded to procaine injection. Final judgment on the value of procaine and its derivatives in the prevention of ventricular tachycardia and fibrillation probably should rest on the analysis of a larger number of patients on whom the drugs were used as compared to an equally large number on whom they were not used where most other variables were reasonably constant.

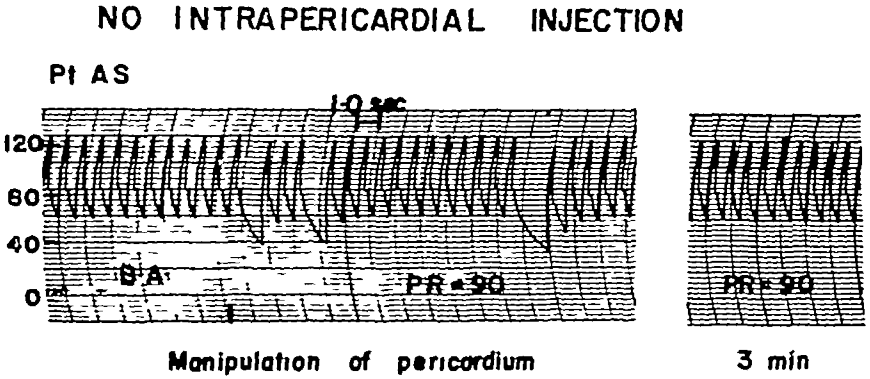

Fig. 3.—No intrapericardial injection. Extrasystoles are noted with pericardial manipulation. There is no change in blood pressure or pulse rate.

It is generally conceded, however, that the prelude to ventricular tachycardia and fibrillation consists in the development of multiple ventricular extrasystoles. These were observed in all the patients to whom procaine had been given and in almost all of those to whom it had not been given. The duration was short in both groups. In this study, it is clear that procaine did not prevent the development of arrhythmias as compared to similar operations without its use. Digitalization does not appear to exert an influence since similar findings were present in digitalized and nondigitalized hearts. The health of cardiac muscle, in contradistinction to that of valves, was not a factor since the healthy muscle in the patients with pulmonic stenosis behaved like the diseased muscle of the patients with rheumatic heart disease.

A further thesis of this discussion is the fact that the use of procaine within the pericardium or the heart muscle may be harmful. The fact that the desired protection against arrhythmias is not accomplished is perhaps of lesser importance than is the circulatory disability imposed by the drug. In the overwhelming majority of patients (90 per cent) tachycardia of clinical significance developed and hypotension was produced in 45 per cent. In patients whose myocardial reserve is severely limited, the induction of tachycardia may precipitate so great a fall in cardiac output as to be a serious physiologic threat. These complications were not observed when no procaine was used or when saline was injected in its place. It can be concluded, therefore, that the stimulation of a needle and the effects of injected fluid do not cause the tachycardia and the hypotension observed in these patients. It is truly an effect of procaine, presumably because of systemic absorption that comes on almost immediately and persists for not less than two minutes and frequently as long as ten minutes

SUMMARY AND CONCLUSIONS

1 The injection of procaine into the pericardial sac or the myocardium did not prevent the development of ventricular extrasystoles in 11 cases of mitral commissurotomy and 20 cases of pulmonary valvulotomy

2 The injection of procaine into the pericardium and into the heart muscle produced tachycardia in a large majority of patients (90 per cent) In approximately one half it also produced hypotension (45 per cent) In 19 comparable control cases these effects were not observed

3 These effects of the injection of procaine are considered harmful in patients who are to be subjected to operations upon the heart and great vessels and particularly harmful in those whose myocardial reserve is already limited

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DISCUSSION

DR ARTHUR VINEBERG, Montreal, Quebec —The question of using procaine is very important, I think, and, although the paper would indicate that perhaps one gets an increase in pulse rate and a drop in blood pressure, this is a very temporary matter In our experiments with internal mammary artery implants in animals where we were dealing with the ventricle we found that we had to use procaine to avoid fibrillation. When we abandoned procaine we had many instances of ventricular fibrillation, and where we used nothing but procaine into the pericardial sac, ventricular fibrillation was a comparatively rare occurrence

With regard to human cases, after reading the recent literature and because, at the time of putting procaine into the pericardium, we had noted the drop in blood pressure and increase in pulse rate which we corrected immediately with Neo Synephrine, we decided to abandon it in two cases, and were sorry that we did so In one case the pulse rate went out of control and we had ventricular tachycardia which nearly terminated fatally Fortunately, putting a suture in the heart brought it back to normal rhythm, showing how sensitive the heart was, and that patient survived So I do not think one should abandon the use of procaine locally without a little more consideration, particularly if working on the ventricle, all who have tried aortic stenotic procedures realize just what can happen even when using procaine

INTRACARDIAC SURGERY WITH THE AID OF ARTIFICIAL OPERATIVE TUNNELS

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DEFECTS of the cardiac septa and valves ideally would be operated upon under direct vision in the open heart in a dry field This type of surgery is being done, but it has not yet advanced to the point of a practicality Until this method is adequately developed artificial devices which afford the surgeon some help in working within the chambers of the heart will continue to be of some interest and perhaps of some use

Such a device has been suggested by Bailey[1] Another has been used successfully to approach the ventricular chambers in animals by Glenn[2] The only such device that has been applied in the treatment of human patients to any extent is the operative well devised by Gross[3] to provide access to the low pressure area of the right auricle

Our efforts have been directed at a universal type of operative tunnel (Fig 1) which would allow approach to the four chambers of the heart and the great vessels, affording the same opportunity for digital visualization and operative maneuver as is utilized in the operation for mitral stenosis via the left auricular appendage We have also aimed at a method which would be as safe as this operation and in which there is no demand for hasty maneuvers and no opportunity for dangerous blood loss

Our early efforts to devise artificial operative tunnels were successful when applied in low pressure areas such as the auricles, and resulted in failure or serious difficulties because of blood loss when applied to the aorta and ventricles

We reasoned that if such a device could be adapted to the aorta, and this would allow safe and accurate surgery on the aortic valve, it would then be considerably less of a problem to utilize the method in approaching other areas within the heart (Fig 2)

In the paper by Glenn[2] in which it is reported that a rubber diverticulum was used to approach the cardiac cavities in twenty-six animals it is stated that in one experiment an attempt was made to sew the diverticulum to the aorta In this experiment bleeding around the suture line was so severe that the animal was lost as a result of hemorrhage

This corresponds to our early experience It was not until we abandoned operative tunnels made of rubber and selected one made of plastic and fabric

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Read at the Thirty-fourth Annual Meeting of The American Association for Thoracic Surgery at Montreal Quebec, May 3 to 5 1954 that we were able to eliminate this bleeding The tunnel device now used has an inner layer of plastic that is smooth, resistant and waterproof The outer layer of cloth strengthens and restrains the plastic at the points of suture In addition the cloth has an adhesive quality when wet with blood This ensures against blood leakage at points of contact with the heart or blood vessel tissues Tunnels which utilize a fabric can be sutured snugly to the aortic incision and, no doubt clotting of blood is promoted between the fabric and the incised blood vessel wall and in the suture holes of the fabric and the blood vessel wall Using many fine interrupted sutures (Fig 3) it is possible to suture this particular operative tunnel to the aortic incision so that there is no blood loss whatsoever

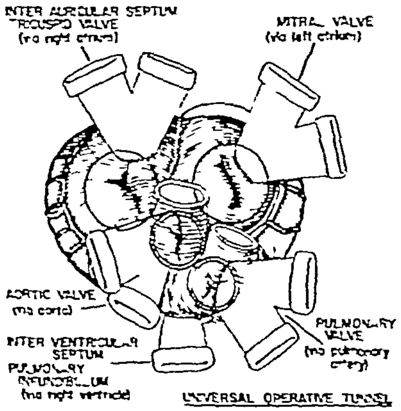

Fig 1

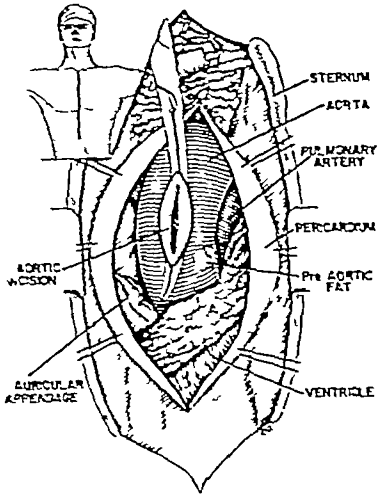

Fig 2

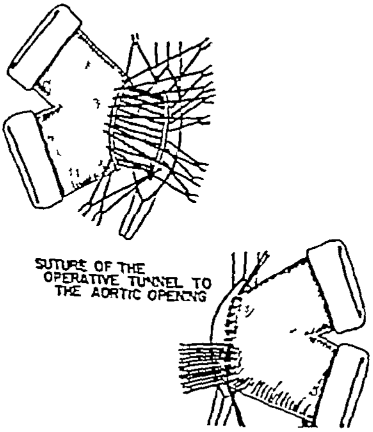

Fig 3

In the course of performing these operations on 20 mongrel dogs* we have developed a technique that regularly allows us to suture the operative tunnel to the aorta, carry out digital and instrumental maneuvers at or below the level of the valve cusps, remove the tunnel device, close the aorta, and have the animal survive.[6]

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* The experimental studies were performed at Saint Mary's Memorial Hospital in Knoxville Tenn.

In the animals the Satinsky clamp suffices for isolation of a longitudinal aortic segment to receive the operative tunnel. On one human patient this instrument proved inadequate because of slipping. We have since utilized a curved clamp with serrated blades (Fig. 2). The principle of the purse string is used here as in the auricular appendage (Fig. 4). Sometimes the root of the aorta is overlapped by the right auricular appendage. In such a case the appendage is retracted by placing a suture in its tip (Fig. 4).

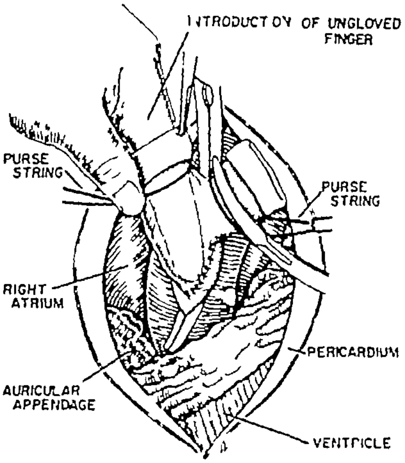

Fig. 4.

The presence of a fat pad over the root of the aorta is constant in human beings (Fig. 2). This must be dissected in order to give a clear access to the vessel. Occasionally we have sutured this tissue to the aortic opening to give more strength in the closure.

In order to place the aortic clamp, there are two maneuvers which are helpful. The vessel is pulled forward by gripping the adventitia with a suitable instrument. The vessel is pushed forward by inserting a finger behind the aorta in the *sulcus transversus* of Theile.

When we first applied this operative method to the treatment of aortic stenosis in a human patient we were using tunnel devices made of rubber of the approximate thickness of a surgical glove.

Experience based upon six animal operations led us to believe we could suture this device to the aortic incision so that there would not be appreciable blood loss. We reasoned that the pressure distal to a stenosed aortic valve would not be appreciably greater than that in the normal aorta of a large animal. This proved to be erroneous.

CASE REPORTS

CASE 1.—Patient M. A. T., aged 39 years, was lost because of excessive bleeding. Blood was lost in considerable amounts at the line of suture of the rubber tunnel to the aorta In addition the tunnel became dilated and distended We feared it would rupture Additional blood was lost in an attempt to break open the calcified commissures with a clumsy instrument similar to a Kollmann urethral dilator

CASE 2—Patient C E C, aged 26 years was lost as a result of bad judgment in placement of the aortic clamp A lip of aorta was isolated anteriorly as usual in the clamp The electrocardiogram immediately revealed an increased depression of the S T segments S T segment depression of some degree was known to have been present for two and one-half years A reapplication of the clamp resulted in improvement of the electrocardiograph picture, but there was still some increased depression of the S T segments over the preoperative status We unwisely decided to accept this situation and proceeded to incise the aorta and suture the tunnel in place We do not like to hurry this suturing It must be extremely meticulous or there will be dangerous leakage After the device was in place but before surgery was done on the diseased valve, ventricular fibrillation occurred Cardiac massage was begun immediately and later the ventricles were defibrillated by means of electric shock. However after a short interval the fibrillation recurred and we were unable to alter the situation. The patient expired one hour and twenty minutes after the initial onset of fibrillation

This patient had significant aortic insufficiency Narrowing of the aorta above the anterior leaflet by application of the clamp undoubtedly resulted in further interference with coronary blood flow Because this interference was prolonged for thirty minutes while the tunnel was sutured in place the coronary insufficiency proved incompatible with survival. Better judgment dictates that a more lateral or posterior application of the clamp be used and that the clamp not be left in place if there is any evidence that its presence decreases the coronary blood flow

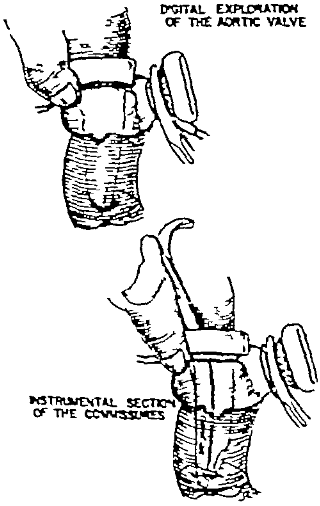

Fig 5

In this operation a tunnel of cloth lined with plastic was used and it was completely satisfactory in that there was no blood loss and there was adequate freedom of approach to the aortic valve

CASE 3—Patient W E N aged 33 years, has been operated on with complete success No blood loss occurred at the line of suture Blood loss about the finger and the instruments used was insignificant In this patient it was possible to open two of the commissures with the finger The third was cut open with a Bailey Glover O'Neil guillotine knife (Fig 5)

CASE 4.—Patient C. B., 48 years old, was operated on for aortic stenosis July 20, 1954 (after this paper was presented), according to the technique herein described. Satisfactory dilation and commissural fracture were accomplished with the finger alone. The surgery was uneventful and the patient was discharged improved on the tenth postoperative day.

Application of this operative method to other areas of the heart is technically less difficult. As a matter of fact, our interest in such a device as is described here was first occasioned by the necessity for exploring the left auricle in a patient who had previously been operated upon for mitral stenosis.

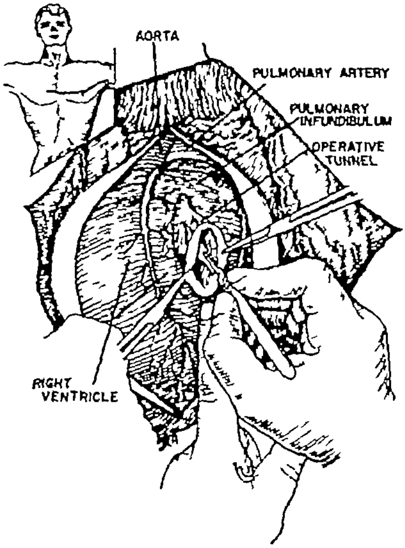

Fig. 6.

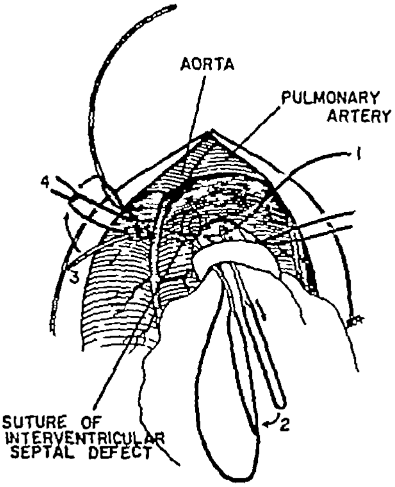

Fig. 7.

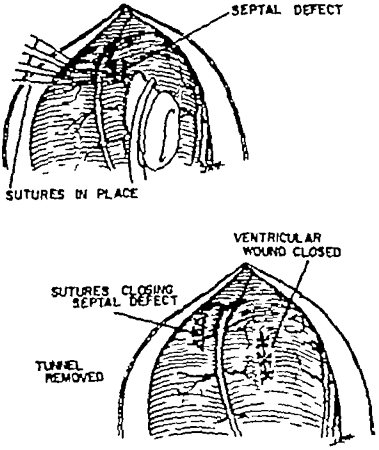

Fig. 8.

From previous experiences we were convinced that the approach through the superior pulmonary vein is at best a hazardous one, and that operative maneuver is markedly limited. Suture of a tunnel device to the auricle of the approximate size and shape of a large auricular appendage allows safe in cision of the auricular wall and freedom for operative maneuver It is suggested that this method of entering the left auricle might be utilized when a thrombosed or calcified appendage is encountered, but sufficient normal auricular tissue is available elsewhere It is further suggested that this method may be found useful when a satisfactory operation for mitral insufficiency is available and is applied to patients previously explored or operated upon for mitral stenosis

The indifferent results which sometimes follow the Brock operation for so called pure pulmonic stenosis led us to apply this method to approach the pulmonic valve through the pulmonary artery in one patient (C D, aged 9 years) We reasoned that this method would allow an accurate assessment of the status of the stenosed valve both before and after it was opened More recent information[4] would seem to indicate that the indifferent or poor results have occurred in patients who had an associated infundibular stenosis and that inadequate pulmonary valvulotomy may not have been responsible for the failures

Using this method in one patient (G H. aged 20 years), we approached the interventricular septum, and closed a septal defect through the infundibular area of the right ventricle The operative technique used was a modification of that described by Kay and Zimmerman.[5] Our modification (Figs 6-8) allows the operation to be done without blood loss and with more latitude for exploration and suture

A similar approach is suggested for operative attack on infundibular stenosis

SUMMARY AND CONCLUSIONS

The authors have devised an operative tunnel made of fabric and plastic which may be sutured to the walls of the heart cavities and the great vessels as an aid in performing surgery on the cardiac septa and valves

Operative technique utilizing the tunnel device has been perfected in animal experiments so that the operations are now regularly performed without blood loss

Application of this method to human patients is now possible even in the high pressure areas of the aorta and ventricles

Further trial of the method is justified particularly in the treatment of aortic stenosis inasmuch as it is the only method available other than cardiotomy in a bloodless field which allows any appraisal of the nature of the pathology before surgery and for any assessment of what has been accomplished

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DISCUSSION

DR W E BLOOMER, New Haven, Conn —Dr William Glenn of Yale could not be here today, and asked me to discuss the paper by Dr Swann, Dr Bradsher and Dr Rodriguez Arroyo with reference to artificial operative tunnels, and to describe the method of approach to the chambers of the heart and great vessels through a closed pouch or diverticulum that was developed at Yale in 1952 and first reported in the *Yale Journal of Biology and Medicine* in February, 1953 The diverticulum used by Dr Glenn is made of molded latex* This method has now been used to approach the chambers of the heart in approximately 100 animal experiments It has been employed successfully in one patient to approach the mitral valve where entry through the auricular appendage was not possible The patient was a 51 year old white woman with Grade III to IV mitral stenosis The incision in the left auricle remained open for more than an hour There were no complications, the patient is living and much improved four months after operation

The following method of sewing on the rubber diverticulum is used The diverticulum is placed between the point of entry of the pulmonary vein and the auriculoventricular groove The finger is passed through the diverticulum into the auricular chamber Here the finger is obturating the incision as closure is begun by taking a deep mattress suture

The method of closure which has been used by Dr Glenn is a "parallel bar method," making use of two pieces of split polyethylene tubing A deep mattress suture is placed through these and the polyethylene prevents the suture from cutting into the myocardium This suture can be snugged up by use of this modified type of Bethune lung tourniquet provided with a long cross bar at the end

The diverticulum has also been used for approach to the right ventricular chamber in an infant with cyanotic heart disease and severe decompensation Although the child did not survive the operative procedure the death of this desperately ill infant was not believed to be due to the sewing on or removal of the diverticulum, or to the exploration of the right ventricle

Before this technique is used in human beings by one not familiar with its use, it is advised that the technique first be applied to the hearts of a number of animals

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* Available at the Seamless Rubber Company New Haven Conn

CARDIOANGIOGRAPHY

PHILIP W SMITH, M.D (BY INVITATION) CHARLES W WILSON, M D (BY INVITATION), HUGH A. CREGG, M D (BY INVITATION), AND KARL P KLASSEN, M D
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IN 1933 Reboul and Racine[1] reported on the direct injection of contrast media into the right and left ventricles of dogs by means of an intercostal approach In 1936 Nuvoli[2] successfully injected a sodium iodide solution intercostally into the left ventricle of a patient with an aortic aneurysm. In 1951 Ponsdomenech and Nunez[3] reported 45 ventricular punctures in 30 human beings without mortality A subxyphoid approach to the diaphragmatic surface of the heart was employed, and 70 per cent Diodrast injected This procedure was designated "Cardioangiography" by these investigators

From a radiographic standpoint the method showed promise of improved visualization of the heart and great vessels when compared with conventional angiocardiography Further evaluation of this procedure seemed warranted

METHOD

Seventy five ventricular punctures were carried out in 18 dogs injecting 70 per cent Diodrast* into the right or left ventricle Electrocardiograms were made before, during, and after the procedure Fluoroscopic or radiographic visualization of the animals' hearts and great vessels was accomplished during the injection. The dogs that died were autopsied and those which survived were sacrificed and autopsied at intervals from immediately to fifty three days after the last ventricular puncture Gross and microscopic observations of the heart and other organs in these animals were recorded

An intercostal approach to the heart was utilized for the first fifteen punctures, but was abandoned after one laceration of a coronary vessel The remaining sixty punctures were done by the subxyphoid approach to the diaphragmatic surface of the heart where the coronary vessels are smaller and more infrequent. No coronary vessel lacerations were encountered by this approach

The technique in dogs consisted of anesthetizing them lightly with intravenous Nembutal and placing them on their right side A 4 inch 17 gauge needle was then inserted in the left subxyphoid region and directed to the diaphragmatic surface of the heart where the right or left ventricle was punctured. Ten cubic centimeters of 70 per cent Diodrast was injected rapidly manually and the fluoroscopic or radiographic observations were made

RESULTS

A cardioangiogram with the needle in the right ventricle (Fig 1) and one with a left ventricular puncture (Fig 2) demonstrate the result obtained in dogs with the injection of 10 c c of the contrast media Serial films taken

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Aided by a Grant from the Central Ohio Heart Association.

Read at the Thirty-fourth Meeting of The American Association for Thoracic Surgery at Montreal Quebec, May 3 to 5 1954

*Supplied by Winthrop Stearns Corporation.

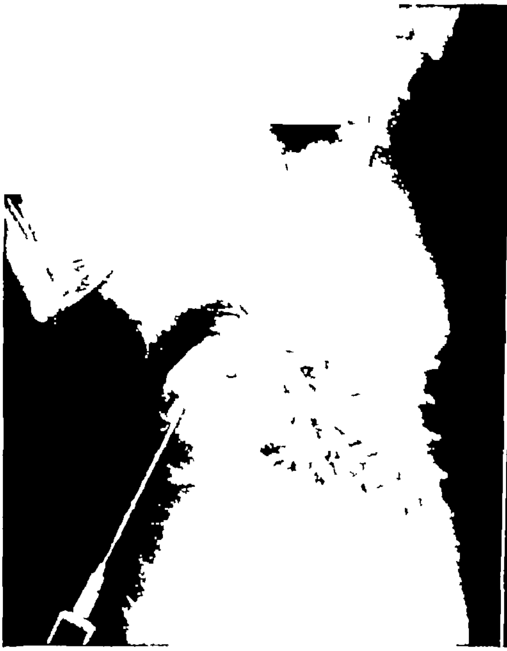

Fig 1

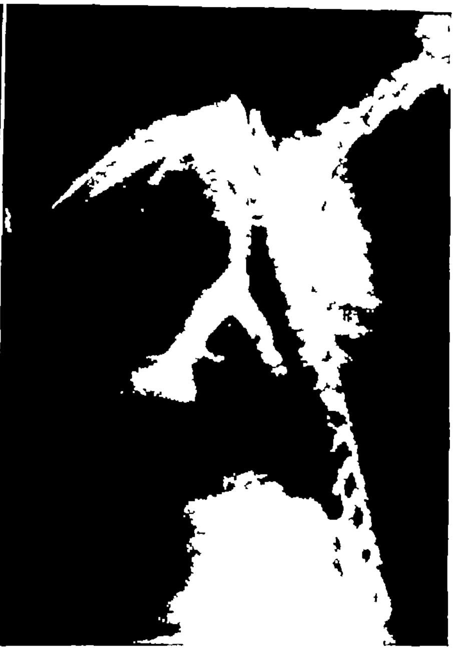

Fig 2

Fig 1.—Cardioangiogram in dog with needle in right ventricle and 10 c.c. of 70 per cent Diodrast injected.

Fig 2.—Cardioangiogram in dog with needle in left ventricle and 10 c.c. of 70 per cent Diodrast injected.

with the Fairchild casette changer* revealed no appreciable loss of contrast from the right to the left side of the heart when the injection was made initially into the right ventricle. Since no leakage occurred through the mitral or tricuspid valves the only dilution of the media is with the blood contained in the ventricle and its outflow tract.

Electrocardiographic changes encountered in the dogs are presented in Table I. When the needle tip encountered the ventricular wall transient extrasystoles constantly appeared. These ordinarily disappeared when access

TABLE I. ELECTROCARDIOGRAPHIC CHANGES IN CARDIOANGIOGRAPHY IN DOGS

TYPE OF CHANGE	FREQUENCY
1. Ventricular extrasystoles	Constant
2. Ventricular fibrillation	1 Occasion
3. Ventricular tachycardia	2 Occasions
4. Ventricular asystole (1-3 beats)	2 Occasions
5. Positional changes	Frequent
6. Other changes	Occasional

was gained to the ventricular chamber. Only one animal developed ventricular fibrillation; this followed five cardiac punctures in rapid succession and the intrapericardial and intramyocardial injection of a portion of the Diodrast. This was the only dog which died as a direct result of the procedure among the sixty subxyphoid punctures Ventricular tachycardia was induced once following the injection of a large amount of Diodrast over a long interval in a purposeful attempt to produce ventricular fibrillation The ventricular tachycardia persisted for forty-eight hours and then reverted to a sinus rhythm The other dog which developed ventricular tachycardia followed an intercostal puncture of the left ventricle and it was sacrificed to determine the cause of the arrhythmia Intramyocardial injection of a portion of the contrast media was found in the wall of the left ventricle The sharp long-beveled needle which we employed in our animal work probably contributed to this danger Presumably this dog would have died, it is included as a mortality from the procedure On two occasions ventricular asystole occurred during injection of the contrast media, but sinus rhythm spontaneously recurred after one to three missed beats Other transient arrhythmias were occasionally encountered during or immediately after injection of the Diodrast

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*Lent by the Picker X-ray Corporation.

TABLE II. COMPLICATIONS OF CARDIOANGIOGRAPHY OCCURRING WITH 15 INTERCOSTAL VENTRICULAR PUNCTURES IN 6 DOGS

TYPE OF COMPLICATION	TIMES OCCURRED	CLINICAL EFFECT
1 Intramyocardial injection of portion of contrast media	1	Ventricular tachycardia, sacrificed promptly but presumably would have died
2 Laceration of coronary artery	1	Cardiac tamponade, died in one hour
3 Perforation of lung	4	Bilateral pneumothorax and pulmonary atelectasis resulted in death of first dog in series other three showed no clinical effect
4 Cerebral damage and renal damage (overdose of 70 per cent Diodrast)	1	Convulsions ending in death twenty four hours later, gross hematuria before death

Other electrocardiographic changes noted included increase or decrease in the rate of the heartbeat, increase or decrease in the height of the QRS complexes, deepening of the Q waves and inversion of the T waves Some of these changes apparently resulted from alterations in the position of the heart induced by the pressure of the needle, they disappeared after withdrawal The significance of these changes is being further evaluated at the present time and the electrocardiographic studies will be reported in more detail elsewhere

TABLE III. COMPLICATIONS OF CARDIOANGIOGRAPHY OCCURRING WITH 60 SUBXYPHOID VENTRICULAR PUNCTURES IN 13 DOGS

TYPE OF COMPLICATION	TIMES OCCURRED	CLINICAL EFFECT
1 Intramyocardial injection of portion of contrast media	1	Ventricular fibrillation and death
2 Mild laceration of left lobe of liver	1	None
3 Intrapericardial injection of portion of contrast media	2	None
4 Renal damage (contrast media other than Diodrast employed)	2	Transient gross hematuria

The complications and mortality occurring as a direct result of this procedure in dogs is depicted in Tables II and III Four of the five dogs which died as a direct result of the procedure were in the group in which the intercostal approach was employed Focal pulmonary hemorrhage where the needle had perforated the lung was found in four of the six dogs in which the intercostal approach was utilized The first dog in our series died of bilateral pneumothorax with massive pulmonary atelectasis as the result of our manipulation in attempting to learn how best to puncture the heart in dogs A viscus other than the heart was known to be injured only once in the series of subxyphoid punctures This dog sustained a small laceration of the liver which was discovered at autopsy four days after the last ventricular puncture The dog had suffered no clinical ill effects The dog that sustained cerebral injury had a total of 55 c c of 70 per cent Diodrast injected into the left ventricle at one time, it also had gross hematuria before death The other two dogs with gross hematuria each had 10 c c of a contrast media other than Diodrast employed Gross hematuria was not observed with doses of 70 per cent Diodrast up to 30 c c Laceration of the anterior descending branch of the left coronary artery resulting in cardiac tamponade convinced us of the increased dangers of the intercostal approach Intrapericardial injection of a few cubic centimeters of the Diodrast did not result in significant electrocardiographic or clinical changes Intramyocardial injection of the media resulted in ventricular tachycardia in one instance, at which time the dog was sacrificed, and ventricular fibrillation and death in the second instance To help obviate this danger, a short-beveled needle was especially made for the human cases, but was not utilized in the animal work Such a needle with a free backflow of blood, should assure free access to the ventricular chamber

The maximum number of ventricular punctures in any one dog was seventeen, accomplished in ten sessions This dog demonstrated no significant permanent electrocardiographic alterations and suffered no clinical ill effects The maximum number of ventricular punctures accomplished in any one dog at one time was five No significant permanent electrocardiographic changes were noted from this repeated trauma but multiple consecutive punctures of the heart have not been employed by us in human cases

Five of the eighteen dogs utilized in this experiment were in poor health from old age or advanced carcinomatosis During the course of the experiments two dogs died of inanition and one died of intercurrent pneumonia These findings were confirmed by gross and microscopic observations made at autopsy One dog died from anesthesia before cardiac puncture was done

Aside from the one dog with massive intrapericardial hemorrhage, only a few cubic centimeters of blood or bloodstained fluid was found in the pericardial cavity at autopsy in those dogs which were sacrificed within three days of the last puncture Those dogs sacrificed after three days did not show evidence of blood in the pericardium and no pericardial adhesions were noted The needle puncture marks in the epicardium and myocardium were often difficult to identify at autopsy but minute subepicardial and intramyocardial areas of hemorrhage were sometimes visible in those dogs sacrificed in the first few days after the last ventricular puncture The endocardium rarely showed evidence of the site of puncture In the two dogs with intramyocardial injection of the Diodrast there was extensive intramyocardial hemorrhage and the heart wall was locally swollen and discolored The later gross patho logic changes found in dogs sacrificed at intervals up to fifty-three days after the last ventricular puncture consisted in the formation of a tiny patch of fibrinous exudate on the epicardial surface over the visible needle puncture sites finally progressing to focal scarring. Microscopically, the early changes noted at the site of puncture in the myocardium were focal hemorrhage followed by focal inflammatory reaction. Focal scarring was the end result, often detected only microscopically.

DISCUSSION

It is apparent that during the investigation of cardioangiography in dogs most of the complications were encountered which theoretically could be anticipated. The dangers of cardioangiography as they were assessed in animals and the measures adopted to minimize such dangers in application of this method to patients are summarized in Table IV. Cardioangiography has been undertaken in six human cases without mortality.

TABLE IV DANGERS OF CARDIOANGIOGRAPHY AND MEASURES ADOPTED TO MINIMIZE THESE DANGERS

DANGER	MEASURE TO MINIMIZE DANGER
1. Intramyocardial injection of contrast media	Short beveled needle with free backflow of blood
2. Coronary vessel laceration	Single puncture of diaphragmatic surface of heart
3. Myocardial ischemia	Rapid injection of limited quantity of contrast media
4. Ventricular fibrillation or cardiac arrest	Oronasal oxygen during procedure, continuous electrocardiograph during procedure, being fully prepared for cardiac resuscitation
5. Perforation of other viscus	Decompression of stomach, proper direction of needle
6. Cerebral or renal damage from contrast media	Limited quantity of contrast media

The procedure is accomplished painlessly with local anesthesia in a properly sedated patient. However a competent anesthetist is at hand and provisions are taken to insert an intratracheal tube and to carry out resuscitative measures should they become necessary. Thoracotomy instruments are available in the event that cardiac massage or cardiac defibrillation is required. Preliminary electrocardiographic tracings are made with the usual leads. An intravenous infusion of saline is usually started and a pint of blood is held in reserve. Procaine was given intravenously during the procedure in one patient.

The equipment (Fig. 3) used for cardioangiography is simple and readily available. The patient is placed on his back or with the left side tilted forward to any desired degree. A small incision is made in the anesthetized area of the skin in the left subxyphoid region. A 15 gauge 5½ inch short-beveled needle attached to a 20 c c Luer Lok syringe containing 20 c c of 70 per cent Diodrast is employed. A continuous electrocardiographic tracing is started as the needle is inserted through the incision in the skin and the operator is kept informed of any significant alterations in the pattern. The needle is advanced superiorly beneath the costal margin more toward the patient's left to puncture the left ventricle and more toward the midline to puncture the right ventricle. When the tip of the needle contacts the heart the operator is aware of the pulsation and the needle is advanced into the ventricle The flow characteristics and the color of the blood coming back into the syringe determine which ventricle has been entered In one instance where puncture of the left ventricle was desired, the right ventricle was entered first and it was necessary to traverse the interventricular septum before access to the left ventricle was obtained As soon as a free backflow of blood has been obtained, the Diodrast is injected as rapidly as possible and the proper x-ray exposures are made It is important to hold the needle steady while it is in the heart, not only to maintain its proper position, but also to prevent the needle tip from flopping around and inducing further ventricular extrasystoles Immediately after the injection the needle is withdrawn and the patient's vital signs are carefully observed for a period of fifteen minutes Further electrocardiographic tracings are made at intervals during this period of time The patient is then returned to his room and further carefully observed for the next twenty-four hours, particularly for cardiac tamponade The paucity of coronary vessels on the inferior surface of the heart makes this complication unlikely but not impossible Another electrocardiogram is made the following day

The question of aneurysm was raised in an elderly lady with a superior mediastinal tumor Twenty cubic centimeters of 70 per cent Diodrast was injected into her left ventricle and the resulting cardioangiogram (Fig 4) showed the tumor to be extravascular At operation it proved to be a malignant thymoma Cardioangiography in a young man with an enlarged left ventricle revealed an entirely competent mitral valve (Fig 5)

The amount of Diodrast which can be injected safely into the ventricle is not known At present the quantity is limited to 20 c c The Cuban investigators[3] used 50 c c of the media injected with a measured-pressure device Manual injection was used in our six cases There is no definite evidence that Diodrast has a deleterious effect per se on the coronary vessels or on the myocardium but its known toxicity to the brain indicates that as yet it is not the ideal contrast media for this purpose Pearl[4] passed a catheter through the femoral or carotid artery to the aortic sinus in dogs and could regularly successfully demonstrate the coronary arteries with injection of 4 c c of 70 per cent Diodrast He did not note any electrocardiographic abnormalities with this dosage Presumably any substance which would displace the blood in the coronary arteries for a sufficient period of time to result in myocardial ischemia would give rise to complications We believe it is important to inject the Diodrast in less than two seconds to reduce its time of coronary transit

Cardioangiography has not been attempted in children and patients with cyanosis The results of the procedure in our six human cases are presented in Table V On the second patient an attempt was made to introduce 40 c c of 70 per cent Diodrast into the left ventricle but because of technical difficulties it was injected too slowly Ventricular fibrillation resulted and cardiac massage was required to restore a sinus rhythm The patient recovered uneventfully though he has an inoperable aneurysm of the thoracic aorta which has bled on several occasions The most likely explanation of the

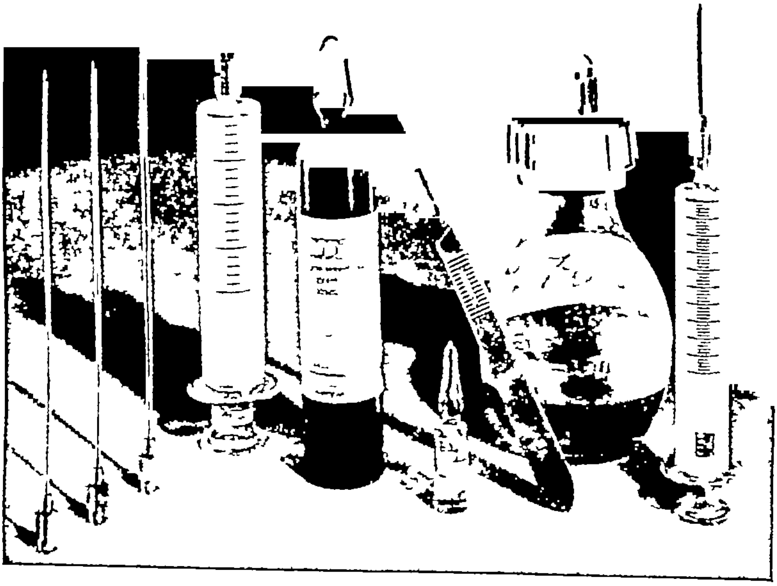

Fig 3—Equipment used in cardioangiography The needles for cardiac puncture in adults are 5½ inches in length and 17 15 and 13 gauge. Note the short bevel

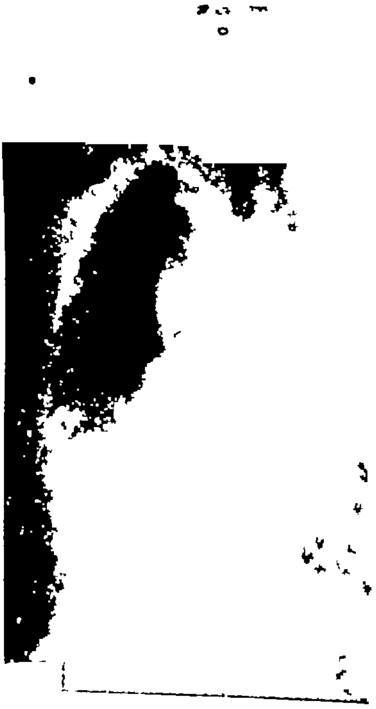

Fig 4

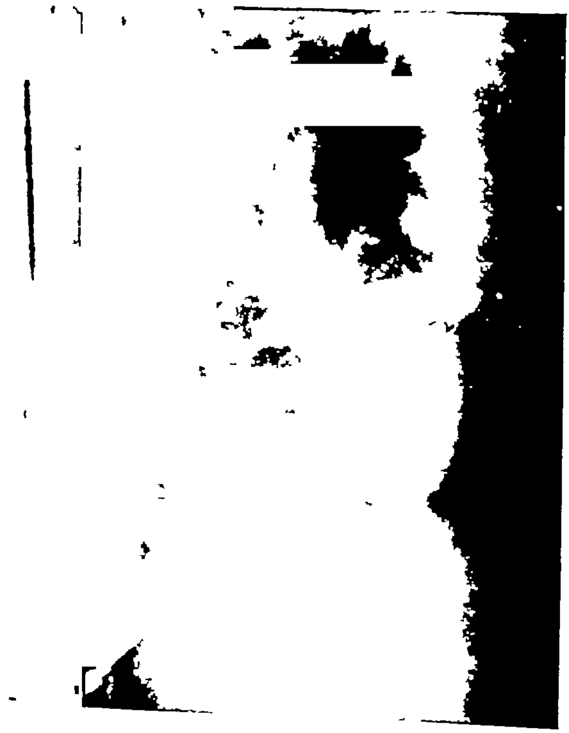

Fig 5

Fig 4—Cardioangiogram in 73-year old woman with a malignant thymoma in the right anterior superior mediastinum. Twenty cubic centimeters of 70 per cent Diodrast was injected into the left ventricle.

Fig 5—Cardioangiogram in a 30 year-old man with an enlarged left ventricle and a competent mitral valve (see arrow) Twenty cubic centimeters of 70 per cent Diodrast was injected into the left ventricle

ventricular fibrillation in this case was the rather prolonged period of myocardial ischemia due to the prolonged coronary transit of the media The radiograph showed the coronary arteries filled with Diodrast No significant complications were encountered in the other five cases

The number of cases reported here is not sufficient to evaluate the possible radiographic advantages of the method Sufficient promise has been shown to indicate that the theoretical advantages may be realized Better delineation of the topography of the left side of the heart, the mitral and aortic valves, and left-to-right shunts should be possible with this method The presence of mitral regurgitation was demonstrated in two cases by Nunez and Ponsdomenech,[5] and in one case by us Rapid serial x-ray exposures will probably be required to realize the full value of the procedure

TABLE V CARDIOANGIOGRAPHY IN HUMAN BEINGS

PATIENT	AGE (YR)	WEIGHT (KG)	DIAGNOSIS	COMPLICATIONS OF PROCEDURE	ELECTROCARDIOGRAPHIC CHANGES	CLINICAL EFFECT
C M	43	93	Aneurysm of innominate artery	Distended stomach entered once	Ventricular extrasystoles, ventricular asystole	No harmful effect
J D	61	60	Bleeding aneurysm of arch and descending thoracic aorta	40 c c 70 per cent Diodrast injected in 5 sec.	Ventricular extrasystoles, ventricular fibrillation	Cardiac massage, sinus rhythm restored in 180 sec , uneventful recovery
M L	73	52	Malignant thymoma	None	Ventricular extrasystoles	No harmful effect
F R	30	70	Coarctation of aorta	None	Ventricular extrasystoles	No harmful effect
A. C	39	70	Mitral stenosis, regurgitation (?)	Access to right ventricle but not left	Ventricular extrasystoles	No harmful effect
J L	44	64	Coarctation of aorta, mitral insufficiency	None	Ventricular extrasystole	No harmful effect

SUMMARY AND CONCLUSION

1 The technique and complications of cardioangiography in dogs and human beings have been presented

2 Cardioangiography when properly applied with certain safeguards may prove to be of value in the radiographic differential diagnosis of lesions of the heart and great vessels

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COMPOSITE VENOFASCIAL AUTOGRAFTS   CREATION AND EMPLOYMENT

AN EXPERIMENTAL STUDY

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CURRENT development of the blood vessel bank and the use of homologous arterial grafts have extended the therapeutic scope of vascular surgery It is now a practical consideration to surgically attack segmental disease of the aorta and its major trunks by resection and replacement with homologous transplants With the demonstration of tissue survival and low incidence of degeneration in experimental autogenous vascular grafts, the employment of such native grafts becomes desirable The additional fact of the indispensability of the human arterial tree makes any source of workable autologous tissue tubes welcome It was with this background in mind that this experimental study was undertaken to test the feasibility of forming composite autologous tubes for vascular transplantation.

METHOD

Apparently healthy dogs weighing between 18 and 30 pounds were employed In the initial study the feasibility of forming a vein-lined fascial layer was tested by the implantation of external jugular vein segments on fascia The fascial sites used were fascia lata, lumbodorsal fascia, fascia of the external oblique, and rectus abdominis

Further experiments were then designed in which the freshly-sutured venous segments were placed on fascia and were wrapped together around nonreacting plastic stents (polyethylene and methyl methacrylate), undisturbed fascial pedicles at both ends of the stent maintaining blood supply The tissue tubes with stents were in situ for periods ranging from seven to fifty-two days before recovery and transplantation into the aorta

Nineteen such venofascial tubes were recovered and transplanted as autografts in the thoracic and abdominal aorta for periods of 2 to 156 days before aortograms were taken and the animals sacrificed for gross and histologic study (Fig 1)

RESULTS

In control sections of fresh segments of the external jugular vein placed on the fascia of the external oblique and rectus abdominis the anatomy of vein and fascia is clearly shown (Fig 2) The tunica intima of the external jugular vein consists of an endothelium supported by a loose fibrillar collag-

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From the Department of Surgery Presbyterian Hospital of Chicago and the Medical School of the University of Illinois Chicago Ill.

enous subintima The tunica media is composed primarily of scattered circular smooth muscle fibers in a collagenous matrix Because both intima and media are extremely thin, these two layers are frequently taken as one The tunica adventitia is the thickest layer and is composed of loose collagenous strands carrying a delicate elastic network This elastic network varies in thickness from two to four fibrils deep, and in some areas is totally absent A wide cleft separates the vein from the thick, coarse collagenous bundles composing the fascial sheet

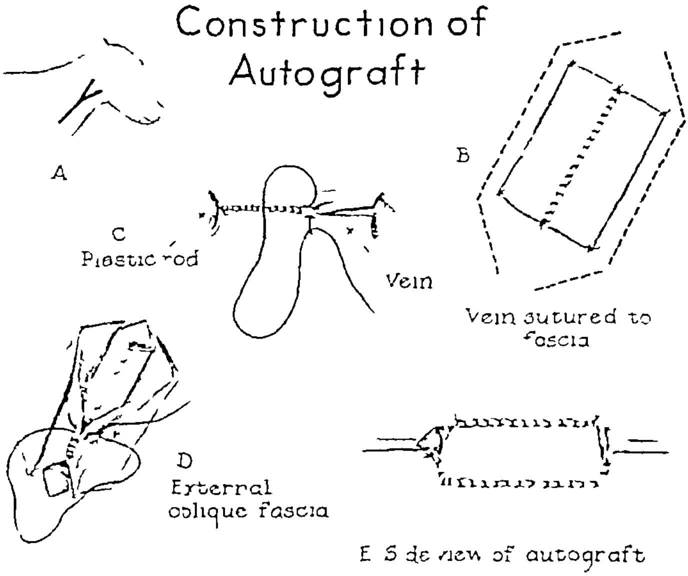


Fig 1

In the first phase of the experiment it was desired to determine the fate of fresh jugular vein segments buried on a fascial bed Segments of external jugular vein measuring from 6 to 8 cm in length were sewn as rectangles on fascia in eight experiments In 9 to 24 days re entry of these sites disclosed serouslike cavities with smooth and glistening surfaces (Fig 3)

Microscopically, the original venous endothelium and subintimal layer had disappeared and were replaced by a loose proliferation of fibroblastic elements forming a fibroserous lining The identifiable remnant of original vein is the narrow fibroelastic layer immediately over the unchanged intact fascia Stains for smooth muscle identification reveal scattered smooth muscle cells which may or may not be in relation to proliferating capillaries (Fig 4)

Grossly, the autologous tubes after implantation with stents for periods ranging from 7 to 52 days retained the tubular shape of the stents and had

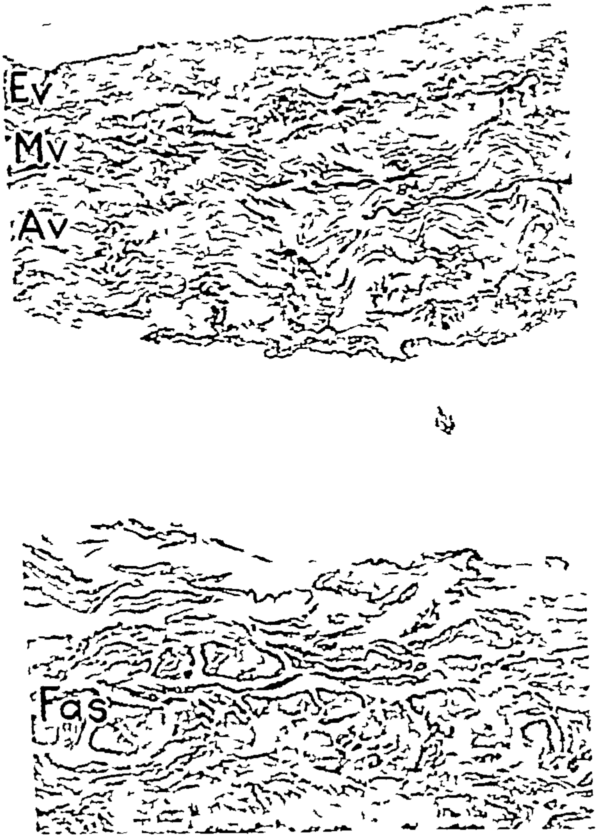


Fig 2—Photomicrograph of fresh external jugular vein segment and fascial bed (control) Ev Endothelium Mv muscularis Av adventitia of vein Fas collagenous bundles of fascia. (Hematoxylin and eosin stain)

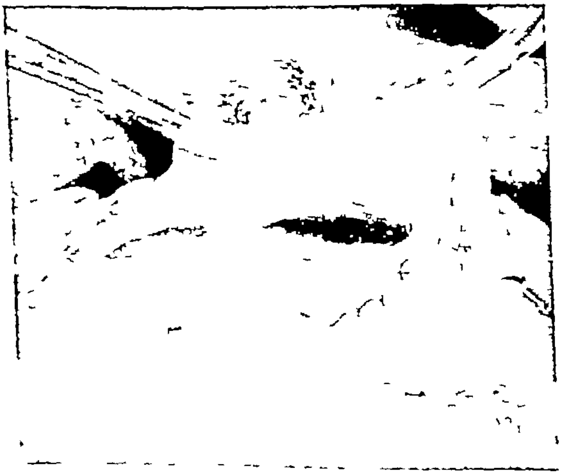


Fig 3—Twenty two day implantation of jugular vein segments on fascia showing fibroserous transformation of surgical cavity

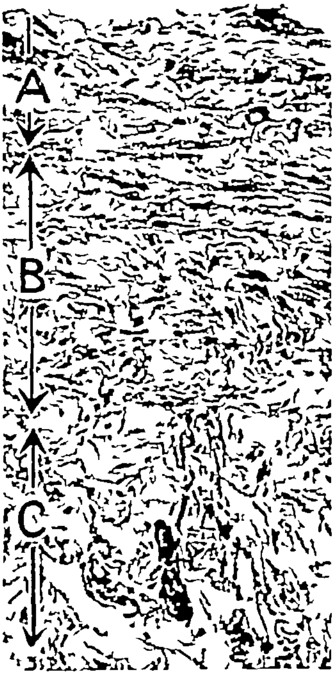


Fig 4 —Photomicrograph of 22 day o brocellular
layer with fibroserous lining which has r ng venous
fibroelastic layer *C* surviving fascial laye n layer *B*
and fusion of venous and fascial layers Acid and
Hematoxylin stains)

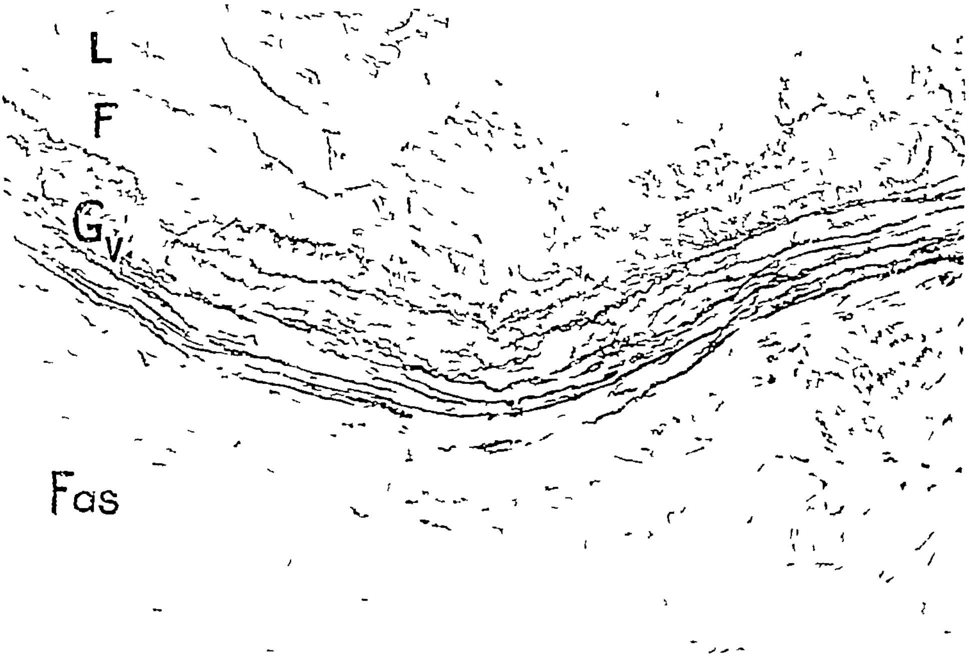
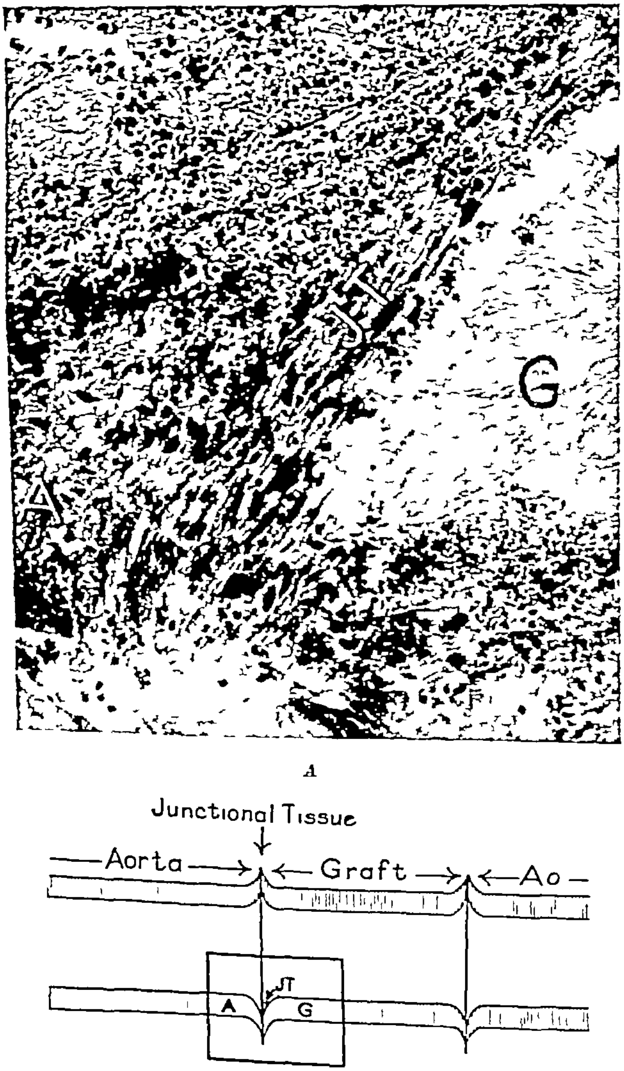


Fig 5 —One day old aortic transplant after 24-day implantation L Aortic lumen F fibrin deposit on graft lining G persisting fibroelastic venous layer Fas fascial jacket (Weigert's elastic stain)

firm walls and margins which could be manipulated and sutured The plastic stents slipped out easily and the tubes were lined with a glistening membrane

Microscopically, the collagenous bands composing the original fascial bed are well preserved and viable Three layers are evident the external heavy collagenous fascial jacket the fibroelastic remnant of the original venous wall and an internal fibroserous lining resting on loose fibrocellular elements (Fig 5)



A

B

Fig 6 — A High power photomicrograph showing proliferating junctional tissue (J T) twenty four hours after grafting Endotheliozation proceeds centripetally from junctional tissue toward center of graft. (Hemotoxylin and eosin stain) B The drawing indicates the location from which the photomicrographic study was made

During the first nine days after aortic transfer, the graft becomes surrounded by vascular granulations and the intimal surface becomes coated with a thin fibrin layer. Reconstruction and resurfacing of the graft proceeds centripetally from the junctional host tissue at the anastomotic lines and creeping endothelization is grossly evident at three weeks. The center of the graft, therefore, is the last zone to be covered by proliferating host endothelium.

Microscopically, within the first twenty-four hours endothelization by ingrowth of junctional tissue begins (Fig 6). The aortic stream covers the graft lining with a thin fibrin layer and replacement of the graft fibroserous

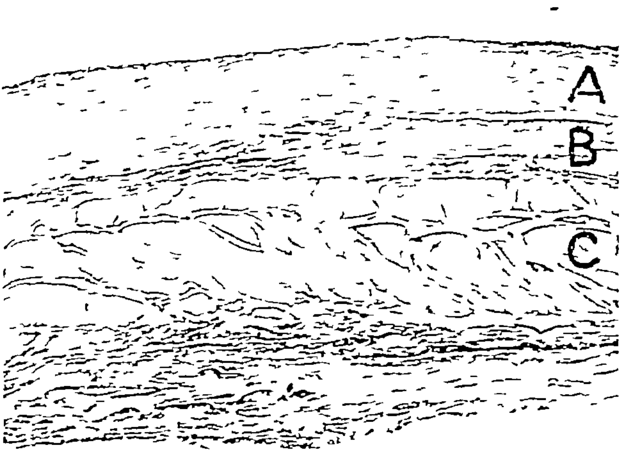


Fig 7.—An aortic graft 121 days old. *A*, Cellular layer the product of junctional tissue replacement. *B*, original fibroelastic venous layer. *C*, original collagenous bundles of fascial jacket. (Hematoxylin and eosin stain.)

Fig 8.—Gross appearance of 121 day old aortic graft.

lining proceeds by fragmentation, hyaline degeneration, and absorption. The proliferating aortic endothelium eventually completely relines the graft (Fig 7). The original fascia and fibroelastic venous layer survive

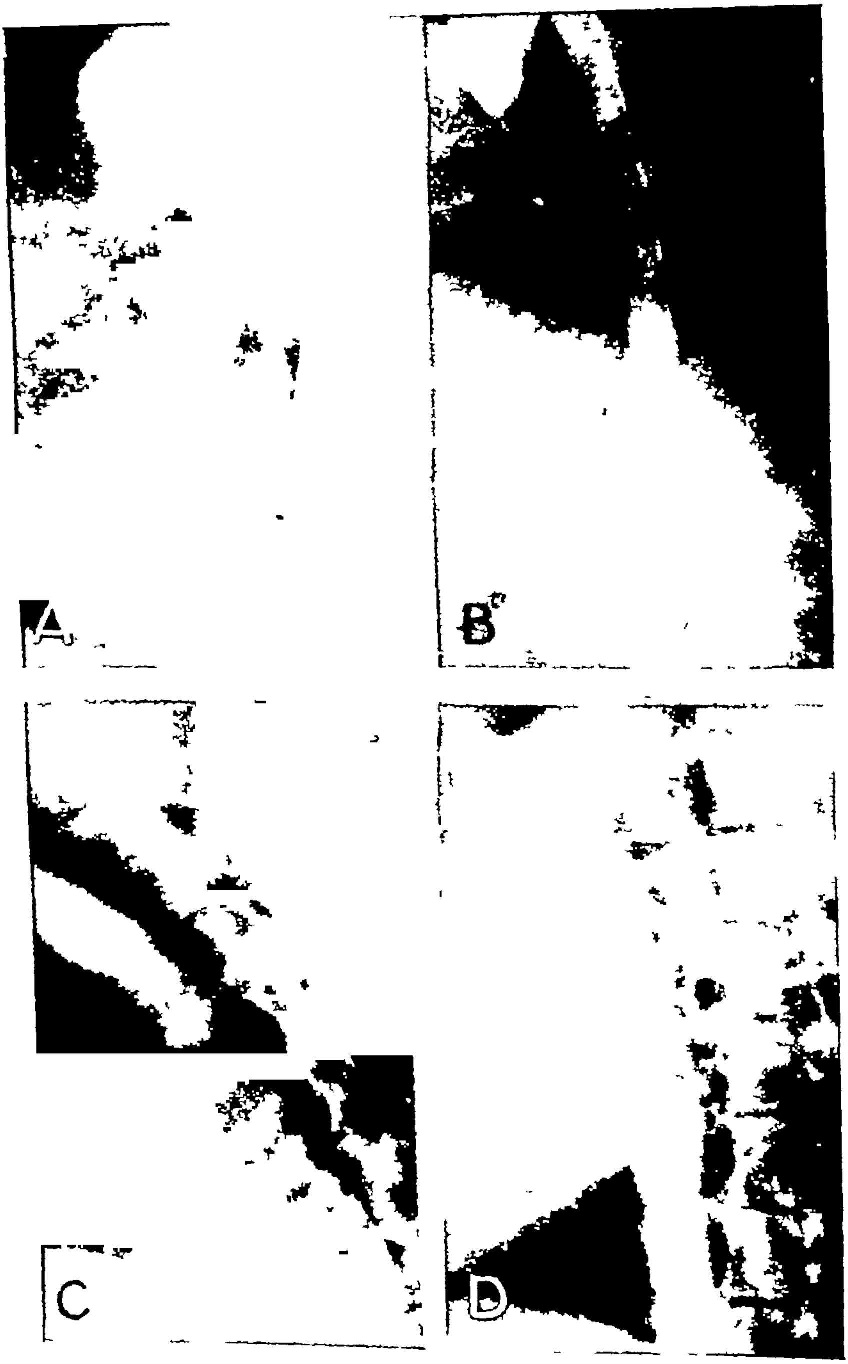


Fig 9.—Retrograde aortograms A 156-day-old graft B 121 day-old graft C 113 day old graft D 54-day-old graft. Most grafts showed disproportion Factors of dispropor tion were not appreciated till late in study Later grafts improved (D)

The evidence of degenerative changes was characterized by microscopic calcific deposits in one graft at 70 days In three grafts focal hyaline deposits were found at 35, 37, and 70 days There was slight dilatation in one graft

DISCUSSION

The search for a ready source of autogenous grafts is well expressed by Sauvage and Harkins[34] when they state, "The hypothesis that from small veins one could make a large caliber graft which, when properly supported, *would not undergo dilatation is most attractive Such grafts would have the* dual advantages of availabilty and autogenicity " The composite autogenous tubes fashioned and transplanted into the arterial stream in this experimental investigation have tested this hypothesis and demonstrated the availability of tubes which can be created as to precalculated dimensions, strength, and contour

Experimentally, viability characterizes autogenous aortic grafts while host connective tissue replacement occurs in homologous transplants In this study the survival and persistence of the venous and fascial elements and the low incidence of degenerative changes are promising as to long term prognosis

The fate of the venous intima is unequivocably death The fibroserous lining which replaces *the venous intima is in turn replaced by the aortic* endothelium in the aortic stream

One graft in this series was found to have significant dilatation However, disproportion *between graft and the recipient aorta was prevalent* initially in the study until the factor of disproportion was appreciated

SUMMARY

1 An experiment to test the feasibility of forming composite autologous tubes was undertaken

2 Nineteen such venofascial tubes were recovered and transplanted into the thoracic and/or abdominal aorta

3 The fate of the venous and fascial elements is one of survival except for the venous intima, which disappears early In the aortic stream, proliferating junctional tissue resurfaces the graft lumen with endothelium

4 A method for fashioning composite venofascial tubes for arterial transplantation is presented

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DISCUSSION

DR EGBERT H FELL, Chicago, Ill—I wish to encourage the further work on creation of autogenously vessels We, too, have used homogenous aortic grafts and have been pleased with the early results You all know the unhappy results encountered with all classes of tissue grafts of homogenous origin That is why Dr Chun and Dr Forney have worked so diligently, I have seen the vessels they created and would now be willing to utilize such an autogenous created vessel of vein and fascia as a substitute in the human aorta It is autogenous, it is living material that will live, and should bear up for many years The substitutes of plastic materials that are now being used, particularly those brought out by Dr Blakemore, may make this procedure obsolete However, more time will be needed to prove that When we know how to transplant homogenous tissues, this procedure will be obsolete again, until then, however, I believe greater effort must be concentrated along this line

EXPERIMENTAL ESOPHAGOGASTRECTOMY EVALUATION OF ASSOCIATED GASTRIC-DRAINAGE PROCEDURES

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F HENRY ELLIS, JR , M D ** (BY INVITATION)
ROCHESTER, MINN

ESOPHAGOGASTRECTOMY as performed clinically is frequently complicated by the development of acid-peptic esophagitis [1-4] It has been demonstrated experimentally that esophageal mucosa is extremely sensitive to the effects of acid gastric juice [5, 6] Esophagogastrectomy with removal of all the acid secreting portion of the stomach is rarely followed by esophagitis in the dog [7, 8] A previous study[7] demonstrated the distinct advantages of a procedure for the facilitation of gastric drainage carried out at the time of esophagogastrectomy These include a reduced incidence of postoperative vomiting, maintenance of better nutrition, and longer postoperative survival Pyloromyotomy was the only gastric-drainage procedure used in that study

The present study was undertaken primarily to compare the results of various gastric drainage procedures performed in association with esophagogastrectomy in which the entire acid-secreting portion of the stomach was removed The study was extended in an attempt to evaluate the possible protective effect of these gastric-drainage procedures against development of esophagitis when acid secreting stomach remained after esophagogastrectomy

METHODS

Adult mongrel dogs varying in weight from 6 7 to 19 kg were used Esophagogastrectomy was carried out under anesthesia induced by intravenous administration of pentobarbital sodium, the technique has been described previously[7] Briefly, this consisted of mobilization and resection of portions of the stomach and esophagus through a thoracotomy incision The vagus nerves were divided A tube of remaining stomach was fashioned by closing the lesser curvature portion End to end anastomosis between stomach and esophagus was carried out

The amount of stomach removed from the various groups of dogs is shown diagrammatically in Fig 1 In Groups 1, 2, and 3, the stomach was transected at the proximal level of the antrum, thus removing the entire acid secreting portion of the stomach Total gastrectomy and esophagoduodenostomy were performed in Group 4 In Groups 5, 6, and 7, only 70 to 80 per cent of the acid secreting portion of the stomach was resected.

Pyloromyotomy was performed in Groups 1 and 5 A long incision was made over the antrum, pylorus, and duodenum, all the layers superficial to the mucosa were carefully incised so that the pyloric sphincter was effectively divided and the mucosa pouted out through the incision

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Pyloroplasty was performed in Groups 2 and 6 A longitudinal incision through all layers was made over the antrum, pylorus, and duodenum The incision was then closed in a transverse direction with an inner running catgut suture and an outer layer of interrupted silk sutures

Antiperistaltic gastrojejunostomy was performed in Groups 3 and 7 The jejunum at a point just beyond the severed ligament of Treitz and at a point approximately 18 cm from the pylorus was anastomosed to the anterior wall of the most dependent portion of the remaining stomach Anastomosis was carried out with an inner running catgut suture and an outer layer of interrupted silk sutures

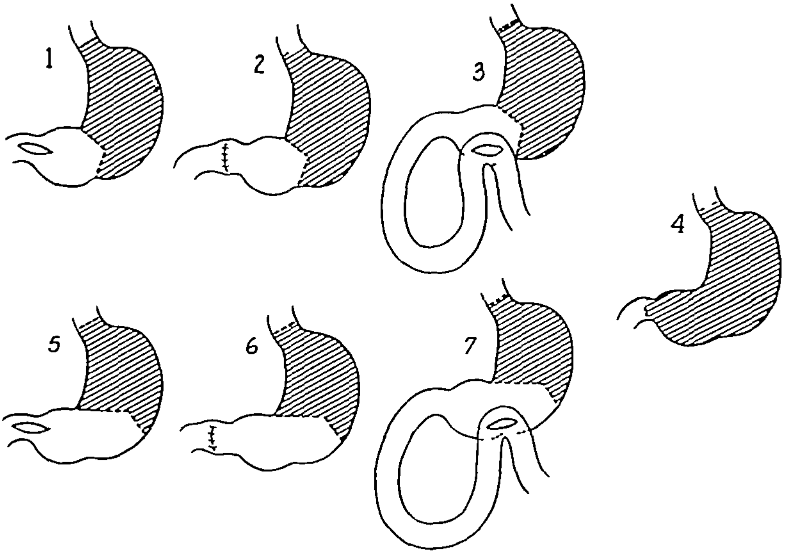

Fig 1 —Types of operative procedures done in the various groups of dogs The shaded areas indicate the amount of stomach resected

In all groups, the newly constructed esophagogastric or esophagoduodenal anastomoses were placed well within the thorax. Results in Groups 1 and 5 have been reported previously[7]

Postoperatively the dogs received nothing but water by mouth for two days They were then given one feeding a day of a standard kennel ration Studies of the gastric secretory response to histamine were made in Groups 2, 3, 6, and 7 before death of the animals The animal was fasted on the morning of the test, 20 minutes after the subcutaneous injection of 1 mg of histamine diphosphate, the stomach contents were aspirated and titrated for free acid

RESULTS

A total of 44 dogs was used The results are summarized in Table I

TABLE I ESOPHAGOGASTRECTOMY AND ESOPHAGITIS IN DOGS

GROUP	PER CENT OF ACID SECRETING STOMACH RESECTED	DRAINAGE PROCEDURE	DOGS	ESOPHAGITIS AT NECROPSY		
				LINEAR ONLY	ULCERS*	NONE
1	100	Pyloromyotomy	8	2	0	6
2	100	Pyloroplasty	5	1	2	2
3	100	Gastrojejunostomy	6	0	5	1
4	Total gastrectomy	Esophagoduodenostomy	5	4	0	1
5	70 80	Pyloromyotomy	6	3	3	0
6	70 80	Pyloroplasty	6	3	3	0
7	70 80	Gastrojejunostomy	8	1	7	0

* All dogs with ulcerative esophagitis had associated linear esophagitis

Group 1—Eight dogs underwent concomitant pyloromyotomy and esophagogastrectomy with removal of all the acid-secreting portion of the stomach Postoperative vomiting was not a major problem in this group All the animals lost weight but not as much nor as rapidly as in the other groups Two dogs died 23 and 25 days after operation, necropsy did not reveal esophagitis or the cause of death The remaining 6 were killed by an overdose of pentobarbital sodium from 95 to 137 days after operation A minimal degree of linear esophagitis was observed in 2 dogs, the remaining 4 showed no esophagitis Thus, of 8 dogs in this group, none had significant degrees of esophagitis

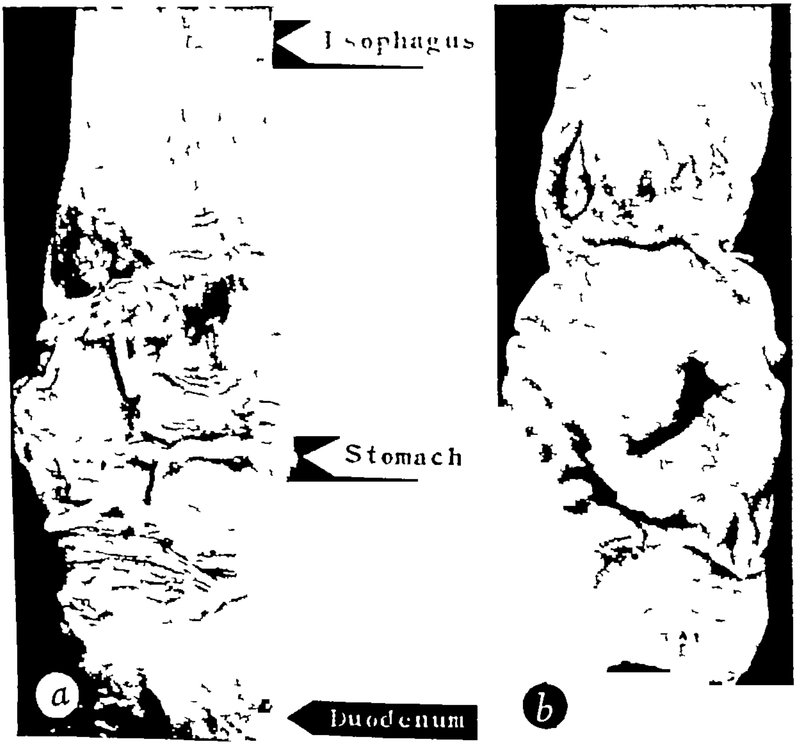

Fig 2—*a* Esophageal ulcer present at necropsy seven months after resection of entire acid secreting portion of stomach and concomitant pyloroplasty *b*, Esophageal ulceration present at necropsy 31 days after resection of entire acid-secreting portion of stomach and concomitant gastrojejunostomy

Group 2—Five dogs underwent concomitant pyloroplasty and esophagogastrectomy with removal of all acid-secreting stomach. Postoperative vomiting was more frequent and more severe than in the dogs in Group 1 All the animals lost weight Three dogs died of inanition 42, 62, and 111 days after operation, necropsy revealed ulcerative esophagitis in 1 and no esophagitis in 2 The other 2 dogs were killed 211 and 226 days after operation, necropsy revealed ulcerative esophagitis in 1 (Fig 2, *a*) and mild linear esophagitis in the other Thus of 5 dogs, 2 had esophageal ulcers and 1 had esophagitis

Group 3—Six dogs underwent concomitant gastrojejunostomy and esophagogastrectomy with removal of all acid secreting stomach Vomiting was a consistent feature of the postoperative course, and rapid loss of weight occurred in all dogs in this group. Five animals died of inanition 15 to 93 days after operation; necropsy revealed ulcerative esophagitis in 4 (Fig. 2, *b*) and no esophagitis in 1 dying at 44 days. The sixth dog died 31 days after operation; necropsy revealed esophageal ulceration with perforation of an ulcer into the pleural cavity. *Thus, 5 of the 6 dogs in this group had esophageal ulceration.*

Group 4.—Five dogs underwent total gastrectomy and esophagoduodenostomy. The purpose of this part of the study was to make a comparison between the results in dogs which had alkaline intestinal contents in direct communication with the esophagus and the results in the aforementioned three groups, in which a gastric segment intervened between the esophagus and the small intestine. The incidence of postoperative vomiting in this group was comparable to that in the dogs in Group 2, in which esophagogastrectomy and pyloroplasty were performed. Loss of weight occurred in all animals. Two dogs died of inanition 25 and 100 days after operation; the remaining 3 were killed 90, 135, and 168 days after operation. Necropsy revealed no esophagitis in 1 and linear esophagitis in 4.

Group 5.—Six dogs underwent concomitant pyloromyotomy and esophagogastrectomy with removal of only 70 to 80 per cent of the acid-secreting portion of the stomach. Vomiting occurred in some of these animals but was not so frequent or so severe as in the dogs in Group 3, in which gastrojejunostomy was performed in association with removal of all acid secreting stomach. Four dogs died of inanition 56 to 147 days after operation; the remaining 2 were killed 122 and 127 days after operation. Necropsy revealed linear esophagitis in 3 and ulcerative esophagitis in 3. *In 1 of the latter, an ulcer had perforated* into the mediastinum; in another, esophageal ulceration had resulted in fatal hemorrhage. Thus, all 6 dogs had esophageal damage.

Group 6.—Six dogs underwent concomitant pyloroplasty and esophagogastrectomy with removal of 70 to 80 per cent of acid secreting stomach. The incidence and severity of postoperative vomiting were great and rather rapid loss of weight occurred in all dogs in this group. Three animals died of inanition 49 to 63 days after operation; necropsy revealed linear esophagitis in 1 and esophageal ulceration in 2 (Fig. 3, *a*). One animal died 22 days postoperatively from perforation of an ulcer on the posterolateral wall of the esophagus into the thoracic aorta, with fatal hemorrhage. The remaining 2 dogs were killed 54 and 97 days, respectively, after operation; necropsy revealed severe linear esophagitis in both. *Thus, of 6 dogs, 3 had esophageal ulcers and 3 had esophagitis.*

Group 7.—Eight dogs underwent concomitant gastrojejunostomy and esophagogastrectomy with removal of 70 to 80 per cent of acid secreting stomach. Postoperative vomiting was more severe and loss of weight more rapid in these dogs than in those of any of the preceding groups. Five dogs died of inanition

15 to 40 days after operation, necropsy revealed ulcerative esophagitis in 4 (Fig 3, *b*) and severe linear esophagitis in 1 Death occurred in another dog 23 days after operation from perforation of an esophageal ulcer into the pleural cavity The remaining 2 animals were killed 17 and 56 days, respectively, after operation, necropsy revealed ulcerative esophagitis in both Thus, of 8 dogs, 7 had esophageal ulcers and 1 had esophagitis

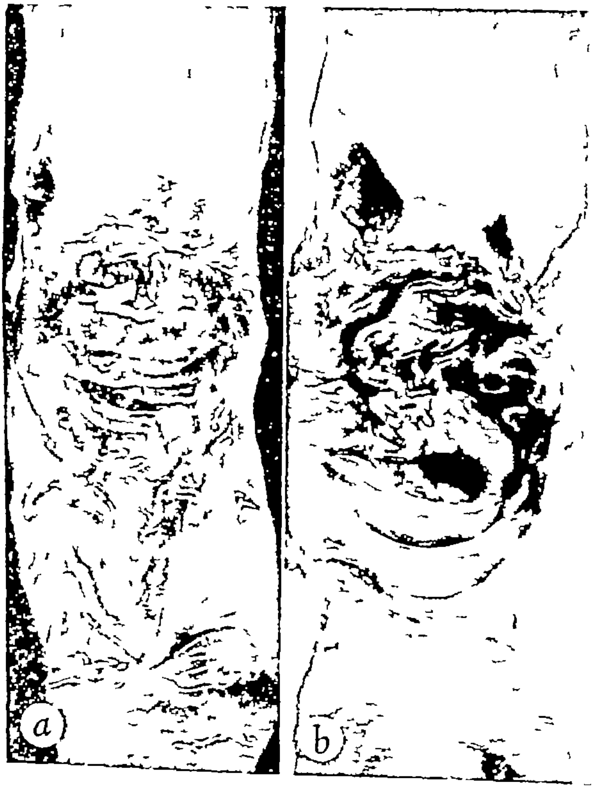

Fig 3—*a* Esophageal ulceration present at necropsy 49 days after resection of 70 to 80 per cent of acid secreting portion of stomach and concomitant pyloroplasty *b* Esophageal ulceration present at necropsy 28 days after resection of 70 to 80 per cent of acid secreting portion of stomach and concomitant gastrojejunostomy

Considering all groups, more rapid loss of weight and shorter survival periods were noted in those dogs in which acid secreting stomach was allowed to remain than in those in which all acid secreting stomach was removed Loss of weight was most rapid and the survival period shortest in those animals in which gastrojejunostomy was used to facilitate gastric drainage Pyloromyotomy with removal of all acid secreting stomach was accompanied by better maintenance of nutrition and longer survival than were any of the other procedures

Results of the studies of gastric secretory response to histamine are summarized in Table II

TABLE II. GASTRIC SECRETORY RESPONSE TO HISTAMINE AFTER ESOPHAGOGASTRECTOMY

GROUP	PER CENT OF ACID SECRETING STOMACH RESECTED	DRAINAGE PROCEDURE	DOGS TESTED*	FREE ACID	
				PRESENT	ABSENT
2	100	Pyloroplasty	3	0	3
3	100	Gastrojejunostomy	3	0	3
6	70-80	Pyloroplasty	6	2	4
7	70-80	Gastrojejunostomy	7	3	4

*Minimum of two estimations per dog.

COMMENT

It has been suggested that pyloromyotomy would be of value in the prevention of the gastric retention that may follow esophagogastrectomy and vagotomy.[9] Other clinical[10, 11] and experimental[7] work has supported this view. Others have advocated gastroenterostomy for this purpose when esophagogastrectomy is performed.[12] Wangensteen[13] has advised against performing a Heineke-Mikulicz pyloroplasty under such circumstances because of the possibility of free regurgitation of alkaline secretions from the duodenum into the esophagus leading to esophagitis.

The damaging effects of alkaline secretions on the esophageal mucosa have been well demonstrated experimentally.[8] The results of the present study confirm these findings. Esophagitis or esophageal ulcers developed in 12 of 16 dogs in which the entire acid-secreting portion of the stomach was removed and alkaline regurgitation facilitated by a Heineke-Mikulicz pyloroplasty, by a gastrojejunostomy, or by total gastrectomy and esophagoduodenostomy. That the esophagitis was not due to acid has been demonstrated by the initial extent of resection and the failure of histamine to stimulate the gastric remnant to secrete acid. It can be assumed, therefore, that the esophageal changes were caused by regurgitation of alkaline secretions into the esophagus.

Pyloromyotomy performed in association with esophagogastrectomy and removal of the entire acid-secreting portion of the stomach resulted in minimal esophagitis in only 2 of 8 dogs. Somewhat similar findings have been reported by Cross and Wangensteen.[8] Apparently regurgitation of alkaline secretions is not so likely to occur with this type of gastric drainage procedure as with pyloroplasty or gastrojejunostomy.

Esophagitis developed in 4 of 5 dogs in which total gastrectomy and esophagoduodenostomy were performed. The esophageal changes, however, were less severe than those occurring in Groups 2 and 3 in which the drainage procedures of pyloroplasty and gastrojejunostomy were employed in conjunction with removal of the entire acid-secreting portion of the stomach. The most severe esophageal damage due to alkaline regurgitation occurred in dogs in which gastrojejunostomy was employed for gastric drainage. It is difficult to explain why esophageal changes as the result of alkaline regurgitation were less severe when the esophagus and duodenum were in direct communication than when the antrum intervened as a reservoir between the esophagus and small intestine.

Previous experimental studies have shown that one must resect the entire acid-secreting portion of the stomach to prevent acid-peptic esophagitis[7, 8]. We theorized that gastric-drainage procedures done in association with esophagogastrectomy in which a portion of the acid-secreting stomach remained might protect against the development of acid-peptic esophagitis. Such protection might be afforded by neutralization of acid gastric contents by regurgitation of alkaline intestinal contents. Furthermore a procedure facilitating gastric emptying might be expected to shorten the time during which ingested food would be in contact with the antrum thus shortening the gastric phase of gastric secretion.

Kiriluk and Merendino[14, 15] found that neither pyloromyotomy nor gastroenterostomy performed in association with esophagogastrectomy and removal of the upper 50 per cent of the stomach was of value in preventing the development of esophagitis. On the other hand recent studies by Brackney and associates[16] indicated that pyloroplasty is of value in reducing the incidence of acid peptic esophagitis after vagotomy and the Wendel procedure in which the mechanism of the cardia is destroyed.

The results of this study indicate that no protection is afforded by any gastric drainage procedure carried out in association with esophagogastrectomy when acid secreting stomach remains since esophagitis or esophageal ulcers developed in all of the 20 dogs undergoing such procedures. Since gastric secretory studies after the subcutaneous injection of histamine revealed the presence of free acid in less than half of the dogs in which acid-secreting stomach remained it is impossible to say whether the esophageal changes were caused by regurgitation of acid or of alkaline secretions. Somewhat similar operations done with pyloromyotomy showed acid consistently present,[17] so one might conclude that in those dogs in which pyloroplasty or gastrojejunostomy was performed free regurgitation of alkaline secretions prevented recovery of free acid from the stomach. The esophageal changes in some of these animals may in fact have been the result of alkaline regurgitation. In any case none of the gastric-drainage procedures employed in this study were of value in preventing esophagitis whatever the cause when acid-secreting stomach remained.

SUMMARY

The effect of various gastric-drainage procedures carried out concomitantly with esophagogastrectomy has been studied in dogs. Pyloromyotomy pyloroplasty and gastrojejunostomy were the procedures employed.

Pyloromyotomy in association with removal of the entire acid-secreting portion of the stomach gave the best results in terms of absence of esophageal damage maintenance of nutrition and length of survival.

Gastrojejunostomy or pyloroplasty performed in association with esophagogastrectomy of similar magnitude was followed by a high incidence of esophagitis and esophageal ulceration as the result of regurgitation of alkaline secretions into the esophagus. The esophageal damage was more severe with these procedures than with total gastrectomy and esophagoduodenostomy

Gastrojejunostomy was the most unsatisfactory gastric drainage procedure from the standpoint of the severity of the resulting esophageal damage, extent of postoperative loss of weight and shortness of postoperative survival

None of the gastric drainage procedures studied protected the esophagus against the development of esophagitis after esophagogastrectomy when 20 to 30 per cent of the acid secreting portion of the stomach remained

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DISCUSSION

DR HERBERT SCHMIDT, Rochester Minn —Dr Neuman and Dr Ellis deserve much credit for calling attention to the fact that surgical excision of the cardia is followed by a high incidence of ulceration at the esophagogastric junction As they pointed out, this occurred in their series of dogs even though the acid secreting portion of the stomach had been excised

In the past it has been felt that two factors are of prime importance in the etiology of this lesion The first is an incompetency at the esophagogastric junction which allows gastric and duodenal contents to regurgitate freely into the distal part of the esophagus The second is the chemical nature of the secretion which is allowed to regurgitate into the esophagus Selye in 1938, found that gastric juice was able to digest the esophagus of the living rat In his experiment, the pylorus was ligated so that the gastric contents were regurgitated into the esophagus In all his animals, hemorrhagic esophagitis developed, and in one instance the esophagus perforated from ulceration. A control group of rats had both the pylorus and the cardia ligated so that the gastric contents would not be regurgitated into the esophagus In this series, no such changes were noted. Since that time, many experiments have been done by many workers, it has been shown that not only the hydrochloric acid of the stomach, but also the alkaline duodenal contents, can cause ulceration in the distal part of the esophagus when they are allowed to regurgitate into the esophagus

I think the most important thing about the work of Dr Neuman and Dr Ellis is that they have emphasized again the hazard of operating upon lesions in the neighborhood of the cardia Because of this hazard, I believe it would be well to avoid surgical treatment of benign lesions such as cardiospasm and strictures of the esophagus before the conservative method of dilation has been given a thorough trial In the past, dilation of the esophagus for these two lesions, when properly done, has given excellent results in a high percentage of cases

PEDUNCULATED ATRIAL FLAPS USED FOR EXPERIMENTAL CARDIAC SURGERY

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THE BEST material for repair or replacement of portions of the heart should be a viable segment of that organ itself Utilizing this concept, a method has been experimentally devised for constructing a pedunculated atrial flap These flaps can be fashioned without obstruction of the normal circulatory flow, without elaborate material, and without long periods of intracardiac exposure The essential idea is to rotate portions of the auricle over the flap and close the base of the defect before the flap is dissected free This procedure differs from the "atrio-septo-pexy" described by Bailey[1] and the "free auricular graft" described by Cohn[2] in that this flap has a pedunculated base for blood supply and a free end which is swung into the cardiac chamber for an intracardiac repair

It is believed that this procedure may have advantages over experimental methods currently in use for repair of septal defects because (1) septal defects can be repaired from the left side (a) allowing the increased left auricular pressure to hold the flap against the septum and (b) allowing an area of auricle to be used which will not result in damage to the conduction system, (2) large septal defects can be covered without constriction of the atrial chamber, and (3) a viable and probably longer lasting repair results The atrial flap when used as a sling for mitral insufficiency is superior to a pericardial sling because it does not cause obstruction or cardiac failure but it does undergo moderate fibrosis and decrease in size Whether the atrial sling retains function after a prolonged period has not yet been determined

This preliminary article covers the results of the use of pedunculated flaps in ten dogs with experimental interauricular septal defect and in ten dogs with experimental mitral insufficiency

METHOD

Large mongrel dogs given endotracheal anesthesia were placed in the right anterolateral position A left fourth intercostal thoracotomy was done and the pericardium opened The auricular appendage was grasped at its tip and pulled anteriorly, tenting it up, and a thin curved noncrushing clamp applied transversely at the base as close to the septum as possible (Fig 1, *A*) Two parallel longitudinal incisions were made through the auricle leaving the center section the width desired for the flap (Fig 1, *B*) The two lateral segments were rotated toward each other over the anterior surface of the middle section

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The anterior edges of the lateral segments were sutured to the auricular wall just proximal to the clamp with interrupted silk sutures (Fig 1, *C*) The posterior edges of the lateral segments were approximated to each other with a running silk suture from the mid point

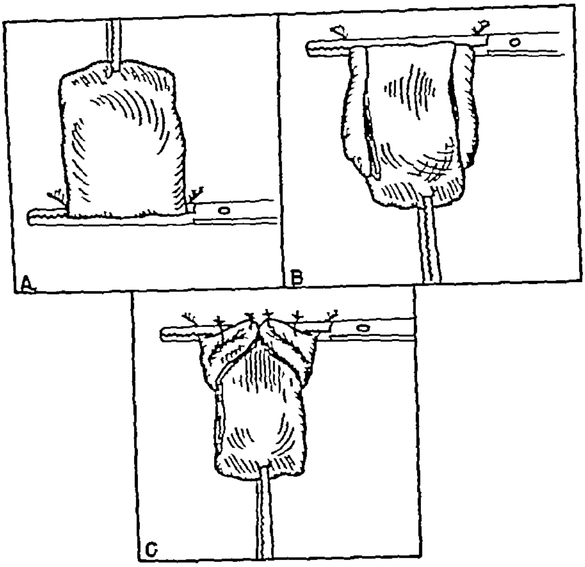


Fig 1—Production of atrial pedunculated flap *A*, Auricular appendage tented up and clamp applied transversely at base. *B*, Two parallel incisions made through the auricle leaving the center section the width desired for the flap *C* Anterior edges of the lateral segments sutured to the auricular wall just proximal to the clamp.

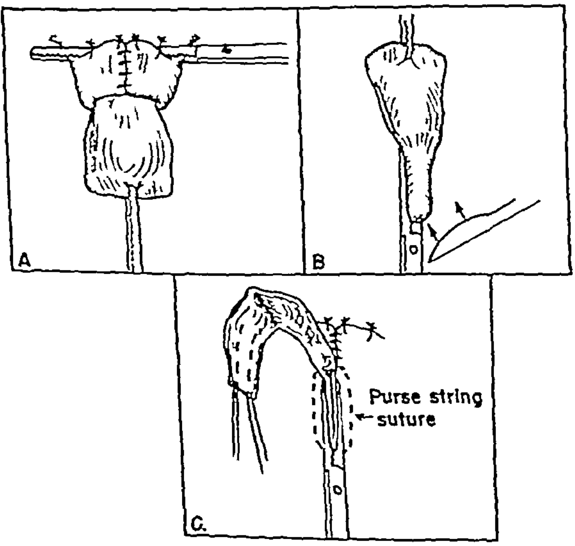


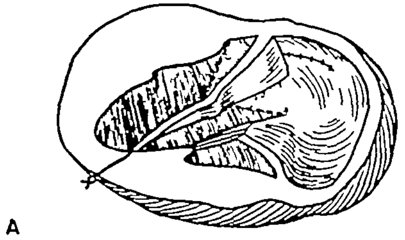
Fig 2—Production of atrial flap (continued) *A* Posterior edges of the lateral segments approximated to each other with a running silk suture. *B* Clamp removed and replaced transversely on the wall of the auricle evaginating auricular tissue to be used for end of flap. Knife showing direction of incision. *C* Flap end cut free and placement sutures on end Purse-string suture proximal to clamp for hemostasis

of the first suture line toward the auricular tip, thereby partially closing the auricle over the future flap (Fig 2 *A*) The clamp was removed and replaced transversely on the lateral wall of the auricle evaginating the distal segment of the flap at the desired width

(Fig 2, *B*) The tip of the flap was cut free and placement sutures were taken at the desired location (i e, at the tip for mitral insufficiency or at each edge for septal defects) (Fig 2, *C*) A purse string suture was placed proximal to the clamp and the clamp was removed. With bleeding controlled by the purse string suture, the flap and placement sutures were passed into the auricle and the placement sutures pushed through the posterior wall of the auricle or ventricle at their desired location, using a flexible probe as a needle Moderate traction held the flap in place while the auricle was closed The placement sutures were threaded on needles and anchored by tying over a small bite of tissue (Fig 3)

Mitral insufficiency was produced by blindly cutting the anterior mitral cusp until a dilatation of the auricle was seen, a definite thrill was palpable, and an increase in atrial pressure was measured The distal end of the flap was pulled through the posterior ventricular wall about 2 cm from the apex as near the septum as possible When the tip of the atrial flap was visible on the surface of the ventricle, it was anchored by two sutures of black silk

MITRAL VALVE SLING



PEDUNCULATED FLAP OVER
INTERATRIAL SEPTAL DEFECT

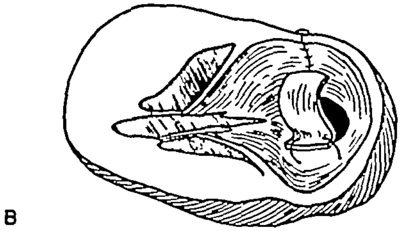


Fig 3 —Final position of pedunculated flap *A* To posterior ventricular wall for mitral insufficiency *B* To the posterior wall of left atrium for atrial septal defect.

Septal defects were made by compression of the superior and inferior vena cava and excising 0 7 to 1 0 cm of the interatrial septum under direct vision from the right chest The right auricle and the right chest were closed and the repair was made from the left atrium at the same operation The edges of the pedunculated flap were anchored by two or three sutures placed by touch through the posterior wall of the left atrium immediately medial to the superior vena cava and medial to the inferior vena cava Care was taken to avoid the pulmonary veins and coronary sinus A technique for repair using the right atrium has also been used Postoperative care consisted of a daily intramuscular injection of 600 000 units of Crysticillin for one week, and routine diet The dogs were sacrificed three months after operation

RESULTS

Mitral Insufficiency—Of the ten dogs that had slings for mitral insufficiency, three were found to have had detachment of the tip with retraction of the flap against the atrial wall One dog died in two days of myocardial infarction due to laceration of the ventricle at the time of cutting the cusp

Six were found to have intact slings, but the slings were reduced in width and moderately fibrotic (Fig 4) Two of the six were adherent to the lacerated cusp and one had twisted upon itself and had the appearance of a fibrous cord

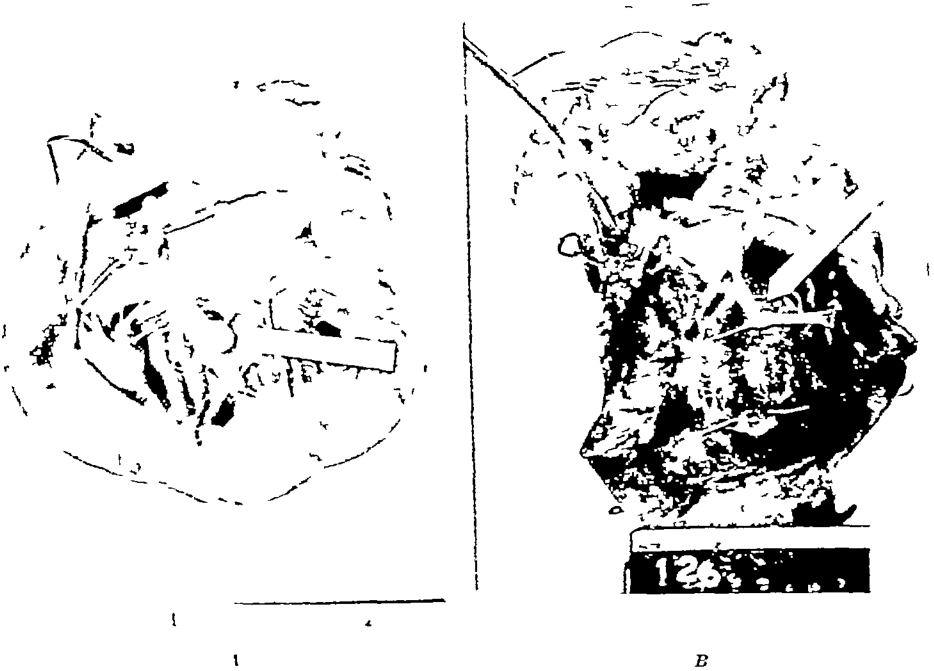


Fig 4 — Atrial flap used as a sling for mitral insufficiency A Appearance two days after operation Pointer showing flap without marked edema, necrosis or thrombosis B Three months after operation Flap showing reduction in size and moderate fibrosis

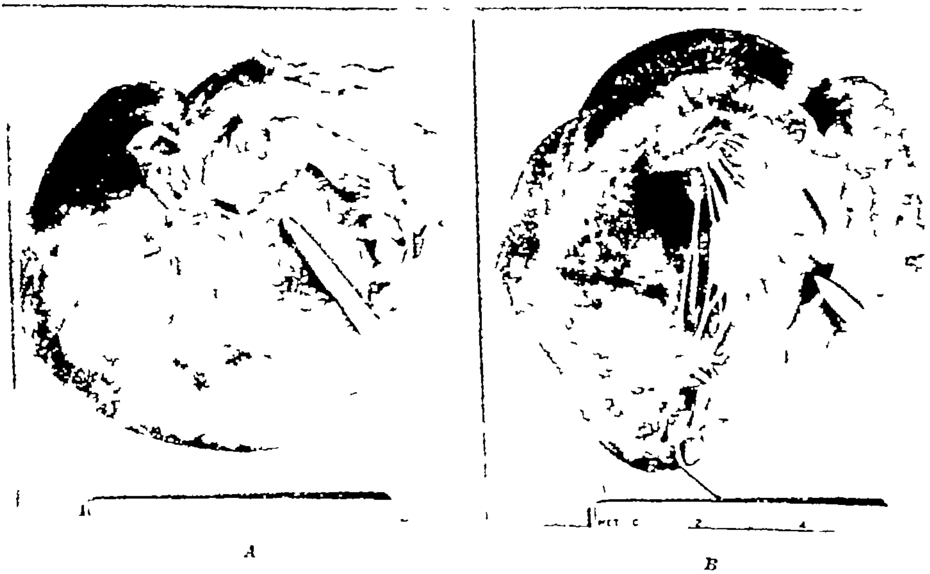


Fig 5 — Septal defect repaired by left atrial pedunculated flap Three months after operation A Appearance from right auricle showing complete closure. B Appearance from left auricle showing flap covered by endocardium.

Reinforcement of the distal one-half of the flap with a running silk suture improved the survival of the tip of the flap at the site of attachment Wider and shorter flaps are now being tried

Pressure studies made at time of operation demonstrated a 4 to 6 cm of saline atrial pressure before laceration of the cusp, 25 to 30 cm after laceration, and 6 to 9 cm after placement of a pedunculated sling If pressure was not reduced, the flap was not correctly placed and replacement of the flap resulted in lowering of the pressure The apical systolic murmur which resulted from the laceration of the cusp persisted postoperatively even though the flap was well placed

Septal Defects—Of the ten dogs with repair of a septal defect, nine dogs had complete closure of the defect and one had 90 per cent closure There were no postoperative deaths due to the production of the flap (Fig 5)

PATHOLOGY

The immediate response in the atrial wall and in the pedunculated flap was a mild edema and diffuse infiltration with polymorphonuclear leukocytes The endocardial surface of the flap became slightly thickened and covered with a very thin layer of fibrin The pericardial surface became covered with a somewhat thicker layer of fibrin, but there was no evidence of thrombosis or embolization At the end of two weeks there was evidence of fibroblastic activity within the flap but viable muscle cells were present After three months much of the flap was replaced by scar tissue, but viable muscle cells were still seen scattered throughout especially at the base Some sections showed mild calcification in the pericardial surface where fat was present, presumably due to local fat necrosis None of the flaps showed myxomatous change, rigidity, or cracking as described to occur in pericardial slings[3, 4]

SUMMARY

An experimental method for the construction of an atrial pedunculated flap without the use of hypothermia, vascular diversion, or vascular obstruction is presented These flaps may be used for the closure of septal defects from the left side and for the formation of a sling to partially alleviate mitral insufficiency Results were excellent in the repair of interauricular septal defects Early experiments using the pedicle flap for a mitral sling showed the need for a more secure method of attachment Later experiments using a reinforced tip were encouraging but further refinements are necessary

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SYNCHRONOUS COMBINED ABDOMINAL-RIGHT THORACIC APPROACH FOR CARCINOMA OF THE MIDDLE AND UPPER THORACIC ESOPHAGUS

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THE technical difficulties encountered when performing esophagectomy and esophagogastrostomy for carcinoma involving the middle and upper thoracic esophagus are admittedly less when the right thoracic approach is used. This is especially true in lesions involving, or in close proximity to, the aortic arch, in which dissection from the left side is more hazardous and difficult. When the right-sided approach is used, the aortic arch acts as a buttress and actually facilitates, rather than impedes, dissection. Following the original suggestion by Ivor Lewis,[1] this method of approach was subsequently favored by Macmanus[2] and by Kent and Harbison.[3] The original drawback attributed to the use of the right thoracic approach was that an associated abdominal operation was required in order to mobilize the stomach. Although these two steps formerly were performed a few days or a week apart, they were soon combined and performed consecutively at the same sitting. It was found that in many instances the patient's general condition deteriorated so markedly between stages that the second operation could not be performed. The left thoracic approach, as described by Sweet[4] and by Garlock,[5] is still accepted as the standard approach to lesions of the cardia and lower third of the esophagus.

Controversy as to the use of the left thoracic approach versus the combined right thoracic and abdominal approach in lesions of the middle and upper portions of the thoracic esophagus has centered around the fact that operative time is prolonged when a combination of approaches is used as is required when the esophagus is mobilized from the right side. In addition, criticism has been directed at the fact that an extensive abdominal operation is sometimes performed and then the lesion found to be inoperable when the thorax is opened. Harrison and Pickett[6] determine resectability first by entering the chest through an anterior intercostal incision. When the lesion is found to be operable, a left upper abdominal incision is made and the cardia and stomach mobilized. A similar approach has been used by DeBakey and Cooley,[7] and by Conerly, Carlson and Scott.[8] Mathewson and Cohn[9] as well as Gaspar and Snyder[10] have also stressed the value of approaching the esophagus from the right side.

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Unfortunately, as emphasized by DeBakey and Cooley, a curative surgical procedure can be applied to only a small number of patients with carcinoma of the esophagus since the disease has extended beyond the limits of total resectability in the great majority of patients by the time surgical treatment is instituted. Ravitch, Bahnson, and Johns[11] point out that the fundamental anatomic relationship of the esophagus to other vital structures and the extensive intercommunicating lymphatic drainage of these organs are such as to preclude the recognized principles of cancer surgery.

In addition to this, the early manifestations of the disease in many instances are not readily recognized by either the patient or the physician. Palliative surgery plays a definite part in the treatment of this condition as it can alleviate the most distressing symptom, namely, inability to swallow. Even though prolongation of life might not be great, life may be tolerable if food can be taken in a relatively normal fashion. Such procedures as palliative gastrostomy and the insertion of indwelling esophageal tubes through the carcinomatous esophagus can in no way compare with the comfort afforded the patient whose swallowing function has been restored after having once lost it.

The philosophy of this matter was perfectly expressed by Chamberlain[12] in discussing the paper by Kent and Harbison[3] at the 1949 meeting of the American Association for Thoracic Surgery at New Orleans. His approach has been to consider all esophageal carcinomas as resectable in the sense that if the stomach can be mobilized, an anastomosis can be accomplished above the lesion. As much of the lesion as possible is then removed. A direct anastomosis is made whenever possible, but, when the esophageal tumor cannot be resected, it is by-passed and the stomach anastomosed to the esophagus above it. In either case this restores the ability to swallow and allows the patient to live three to six months more happily than he would with a gastrostomy.

Modifications of the right sided approach which have variously been employed include a right anterior thoracic or right posterolateral incision in combination with a left or midline abdominal incision. Cervical approach has also been used in conjunction with these when indicated for extremely high lesions. After determining operability through a right posterolateral incision Watson, Luomanen, and Goodner[13] have extended this to a right thoracoabdominal incision. A second operating team is used for the abdominal phase of the procedure. Our modification has merely been in the fact that the abdominal and thoracic phases of the operation have been started simultaneously and performed synchronously somewhat after the fashion of the British surgeons in performing synchronous combined abdominoperineal resection of the rectum.[14] Esophageal carcinoma is thus approached with the attitude that the lesion will be resectable and if not resectable a palliative by-pass procedure will be done to restore deglutition.

TECHNIQUE

Two operating teams are employed. After the patient has been anesthetized and intubated, he is placed upon the operating table with the right thorax elevated at a 45 degree angle rather than a 90 degree angle as in the usual left lateral position Position is maintained by the use of sandbags and adhesive strapping The right arm is suspended in an elevated and forward position This allows the thoracic team and the abdominal team to work simultaneously The thoracic surgeon's work can be facilitated by assuming a sitting position Although operating position is not optimum for either team the inconvenience is not significant Most patients are quite thin and exposure is accomplished without difficulty

A right posterolateral incision beginning in the intrascapular region is made over the sixth rib as far as the anterior axillary line At the same time the abdominal team approaches the stomach through a left paramedian incision the abdomen is explored for lymph node and hepatic metastasis and metastatic nodes along the lesser curvature of the stomach are removed as completely as possible The fifth or sixth rib is removed subperiosteally and the thoracic cavity entered The azygos vein is divided, the mediastinal pleura extensively opened and the esophagus approached While the esophagus and tumor are being mobilized by the thoracic team the blood supply to the stomach is divided by the abdominal team with the exception of the right gastric and right gastroepiploic vessels The vascular arches of the greater and lesser curvatures are carefully preserved This mobilization is sufficient to allow the stomach to be drawn into the apex of the right pleural cavity without tension

Following mobilization of the stomach by the abdominal team the esophagus is amputated at the cardia which is then closed with two rows of sutures a continuous 000 chromic catgut for the inner layer and a row of interrupted 000 silk for the outer layer While this is being done the distally divided esophagus is drawn into the chest by the thoracic team and a new opening is made in the diaphragm anterior to the inferior vena cava The mobilized stomach is then brought through the new diaphragmatic opening This is done to avoid possible postoperative obstruction at the gastric outlet which might occur if the stomach were allowed to remain in the original hiatus Hollingsworth[12] demonstrated that the bulky folds of gastric mucosa could result in obstruction when compressed into the small space between the inferior vena cava and the vertebral column Serious interference with emptying of the stomach can result particularly in view of the loss of tone occasioned by the division of both vagus nerves One is impressed by the narrow space which exists between the inferior vena cava and vertebral bodies when this area is palpated at the time of surgery After the stomach has been brought into the thorax through its new opening the old esophageal hiatus is closed with several interrupted silk sutures by the abdominal team and the abdomen is then closed

The thoracic portion of the operative procedure is concluded with esophagogastrostomy This is performed at a level of at least 2 to 4 cm above the proximal palpable margin of the tumor A site on the anterior aspect of the fundus of the stomach is selected for the anastomosis which is performed throughout with interrupted Lembert sutures of 000 or 4 0 silk The first row of sutures includes the muscular coats of the esophagus and stomach, neither lumen of which has as yet been entered. When the posterior row is completed, an incision is made into the lumina of the esophagus and stomach in a parallel fashion and distal to the previously placed row of sutures. Several small submucosal vessels may require ligation on the gastric side. The second suture row includes all layers of the esophagus and stomach, and is carried completely around from posterior to anterior. The esophagus is amputated and the outer row of interrupted sutures is then continued onto the anterior portion of the anastomosis. The suture line is reinforced when possible with pleura or a small tag of mesentery. The stomach is anchored in place by means of a number of interrupted sutures and the diaphragmatic opening is sutured snugly, but not tightly, around the gastric outlet.

A nasogastric tube is passed into the stomach and connected to Wangensteen suction at the termination of the operation. The lung is re-expanded and the pleural space is drained in the usual manner through a separate stab wound and the intercostal tube connected to water-seal drainage for twenty-four to forty-eight hours. The thoracotomy incision is closed in layers.

SUMMARY

It has been demonstrated by experience that carcinoma of the thoracic esophagus in many instances, especially in the middle and upper portions, is not curable by surgical means because of the extensive nature of the lesion and involvement of adjacent structures. Considerable relief and restoration of swallowing may be afforded such patients by esophagectomy and esophagogastrostomy. Even in nonresectable lesions, symptomatic relief can be afforded by by-passing the malignancy with a proximal esophagogastrostomy. Such a program is readily accomplished by means of a synchronous combined abdominal-right thoracic approach. With two surgical teams operating simultaneously, one in the abdomen and one in the right thorax, the operative time is considerably shortened. By positioning the patient on the table at a 45 degree angle, it is possible for both teams to work comfortably and there is no need for repositioning of the patient at any time. The operation is thus actually a one stage, two team procedure rather than a two stage operation. The procedure is technically less difficult through the right chest and anastomosis is somewhat facilitated for a right-handed operator. In applying synchronous combined abdominal right thoracic approach to lesions of the middle and upper thoracic esophagus, one must maintain the underlying philosophy that resection can be done in all cases, although admittedly palliative in many instances.

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DIFFERENTIAL BEHAVIOR OF ARTERIAL HOMOGRAFTS IMPLANTED IN THE THORACIC AND ABDOMINAL AORTA

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Everett J Schmitz, M D ,*** Lester R Sauvage, M D ,****
Horace G Moore, Jr , M D ,***** Ralph K Zech, M D ,****** and
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THE immediate and essential function of a vascular graft is to conduct an adequate flow of blood This prime prerequisite has apparently been fulfilled on at least a short-term basis by a variety of vascular grafts now available However, the immediate success of a vascular graft may subsequently be overshadowed by undesirable complications Thus it is imperative that the behavior of various types of vascular grafts be clearly defined as to their ultimate fate in the recipient host

Heretofore, information regarding the behavior of arterial homografts has been obtained largely from studies limited to the abdominal aorta This communication presents a comparative study of arterial homografts implanted into the thoracic as well as the abdominal aorta and, in addition, takes into consideration such factors as period of graft preservation, method of preservation, length of graft, and growth of the host animal

MATERIAL AND METHODS

Ninety-eight healthy weanling pigs averaging 13 0 kg had aortic homografts implanted into the thoracic or abdominal aorta Fifty-five of these grafts were into the abdominal aorta, and 43 were into the thoracic aorta The thoracic operations were done through the bed of a resected fifth or sixth rib under intraperitoneal Nembutal and supplemental positive pressure endotracheal ether anesthesia The graft lengths varied from 1 0 to 10 75 cm, while the average graft diameter was 1 08 cm After completion of the anastomoses and determination of necessary measurements of the graft and host

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**** **Professor of Surgery University of Washington Seattle Wash aorta the area was replenished. The lungs were re-expanded and the chest closed in layers without drainage. The abdominal aortic homografts were implanted through a left flank retroperitoneal approach. These abdominal aortic grafts varied in length from 0.60 to 4.90 cm., although one graft measured 5.95 cm. The average diameter of this group of grafts was 0.54 cm.

Following a period of observation in the laboratory for early complications, the pigs were sent to a farm for a period of six to eight months' maturation. Upon attaining maturity, the pigs were slaughtered and the grafts with the adjacent host aorta were removed under the personal supervision of two or more of the investigators. The grafts were inspected, palpated, inflated with air at a pressure of 120 mm. Hg and measured. Grafts believed to be calcified were x-rayed. Photographs were obtained of the external appearance of the inflated grafts as well as of the internal surface after longitudinal section. A portion of each graft was taken for microscopic study.

Further details of the methods and procedures used in these experiments have been reported by Kanar and associates in 1953,[7] Nyhus and associates in 1953,[8] and by Sauvage and Harkins in 1952[10] and 1953.[11]

Arbitrarily, we have designated grafts over 5.0 cm. as "long" and those less than 5.0 cm. as "short" grafts similar to our previous classification with respect to venous autografts reported from this laboratory by Schmitz and co-workers in 1953.[12]

Fresh aortic homografts were those implanted in the recipient animal immediately after removal from a donor pig which in turn usually received some type of preserved graft to re-establish aortic continuity and blood flow. The preserved grafts were kept at 4° C. after immersion in Tyrode's homologous serum media (15 grafts preserved 1 to 120 days), Ringer's homologous serum media (13 grafts preserved 1 to 413 days), heparin saline solution (2 grafts preserved ½ to 1 day), or light mineral oil (36 grafts preserved 1 to 247 days).

RESULTS

The data obtained in these studies will be reported according to the following classification of grafts:

I. Abdominal aorta homografts
  1. Fresh short homografts
  2. Preserved short homografts
II. Thoracic aorta homografts
  1. Fresh long homografts
  2. Fresh short homografts
  3. Preserved long homografts
  4. Preserved short homografts

I. Abdominal Aorta.—

1. *Fresh short aortic homografts of abdominal aorta.* The ten young pigs in this group had grafts implanted for 170 to 254 days. There were no fatali-

ties related to the homografts The grafts showed a growth in length which was equal to the crown-rump (C-R) measurement increase in the animals and the increase in the length of the host aorta However, with respect to the diameters, it was found the average increase in aortic diameter was 165 per cent, while the graft diameter increased an average of only 75 per cent More specifically, 30 per cent of the grafts in this group were found stenotic at slaughter and, therefore, unsatisfactory according to the criteria of Sauvage and Harkins One graft in this series was completely occluded by late thrombosis, but there were no grafts with atheromatous like or calcific changes The changes in these grafts are given in Table I

TABLE I CHANGES IN FRESH SHORT AORTIC HOMOGRAFTS OF ABDOMINAL AORTA

NUMBER OF PIGS	INCREASE IN C-R (%)	INCREASE IN AORTIC LENGTH (%)	INCREASE IN GRAFT LENGTH (%)	INCREASE IN AORTIC DIAMETER (%)	INCREASE IN GRAFT DIAMETER (%)	AVERAGE DAYS GRAFT IMPLANTED	THROMBOSIS (%)	STENOSIS (%)	DEGENERATION* (%)
10	98	98	98	165	74	214	10	30	0

*Degeneration refers to the finding of atheromatous like or calcific changes

2 *Preserved short aortic homografts of abdominal aorta* Forty five pigs comprise this group having grafts implanted for 2 to 287 days during which time the crown-rump measurements increased an average of 93 per cent, while the aortic and graft lengths increased an average of 81 per cent and 65 per cent, respectively The aortic diameter increased an average of 121 per cent while the graft diameter showed an average increment of only 55 per cent Three of the grafts were classified as stenotic five showed early or late thrombotic occlusion, and six grafts showed evidence of calcification or atheromatous-like degeneration

The grafts were preserved in light mineral oil Tyrode's or Ringer's homologous serum media or heparin saline solution at 4° C There was no relationship between the development of late complications and the period of preservation or the nature of the preservative fluid used

The changes observed in this group of grafts are summarized in Table II One graft of this group showed complete preservation of cellular integrity on microscopic examination This graft had been preserved in Tyrode's homologous serum medium at 4° C for one day and implanted in the pig for 195 days

II Thoracic Aorta—

1 *Fresh long Aortic homografts of thoracic aorta* Fifteen grafts were implanted into young pigs which showed an average crown rump increase of 85 per cent over periods ranging from 8 to 321 days In this group the aortic length increased an average of 92 per cent as compared to an average graft

TABLE II CHANGES IN PRESERVED SHORT AORTIC HOMOGRAFTS OF ABDOMINAL AORTA

NUMBER OF PIGS	INCREASE IN C R (%)	INCREASE IN AORTIC LENGTH (%)	INCREASE IN GRAFT LENGTH (%)	INCREASE IN AORTIC DIAMETER (%)	INCREASE IN GRAFT DIAMETER (%)	AVERAGE DAYS GRAFT IMPLANTED	AVERAGE DAYS GRAFT PRESERVED†	THROMBOSIS (%)	STENOSIS (%)	DEGENERATION* (%)
45	93	81	65	121	55	175	50	11	6 6	14

*Degeneration refers to atheromatous like or calcific changes

†Preserved in light mineral oil Tyrode s or Ringer's homologous serum media, or heparin-saline solution at 4° C

length increase of 31 per cent Somewhat similar retardation of "growth" was noted with respect to the graft diameters, although none of the grafts were actually stenotic The changes for this group are tabulated in Table III

TABLE III CHANGES IN FRESH LONG AORTIC HOMOGRAFTS OF THORACIC AORTA

NUMBER OF PIGS	INCREASE IN C R (%)	INCREASE IN AORTIC LENGTH (%)	INCREASE IN GRAFT LENGTH (%)	INCREASE IN AORTIC DIAMETER (%)	INCREASE IN GRAFT DIAMETER (%)	AVERAGE DAYS GRAFT IMPLANTED	THROMBOSIS (%)	STENOSIS (%)	DEGENERATION* (%)
15	85	92	31	78	29	174	13	0	87

*Degeneration refers to atheromatous-like or calcific changes

Thrombosis of the graft was observed in two of the pigs at 19 and 56 days and both grafts revealed calcification on microscopic examination Ten additional grafts showed atheromatous-like formation or calcification on gross or microscopic examination However, one graft in this group behaved like an autograft in that all the cellular elements were intact This thoracic graft remained in the pig for 321 days

2 *Fresh short Aortic homografts of thoracic aorta* This group of seven grafts showed an average length increase of 24 per cent while the host aorta and crown rump measurements increased an average of 72 and 74 per cent, respectively Graft implantations lasted from 35 to 276 days The grafts had an average diameter increase of 24 per cent as compared to an aortic diameter increase of 66 per cent

Although none of these grafts showed stenosis or became occluded, *all* of the grafts showed degenerative changes in terms of atheroma formation or calcification (See Table IV for résume of changes in this group of grafts)

TABLE IV CHANGES IN FRESH SHORT AORTIC HOMOGRAFTS OF THORACIC AORTA

NUMBER OF PIGS	INCREASE IN C R (%)	INCREASE IN AORTIC LENGTH (%)	INCREASE IN GRAFT LENGTH (%)	INCREASE IN AORTIC DIAMETER (%)	INCREASE IN GRAFT DIAMETER (%)	AVERAGE DAYS GRAFT IMPLANTED	THROMBOSIS (%)	STENOSIS (%)	DEGENERATION* (%)
7	74	72	24	66	26	180	0	0	100

*Degeneration refers to atheromatous-like or calcific changes

3 *Preserved long aortic homografts of thoracic aorta* In this group of 13 pigs, the aortic length increased more than the crown-rump measurements of the animals, but the grafts lagged far behind the increments of the host aorta in terms of length as well as diameter so that five of the homografts are classified as definitely stenotic The average changes in these grafts are given in Table V One of these stenotic grafts had complete luminal occlusion at the pig's slaughter 252 days after graft implantation without evidence of collateral vascular channels in the area of the grafted segment One other graft thrombosed 41 days after implantation, but this complication was probably related to an associated lung abscess and a purulent empyema No calcium deposits were found in the thrombosed or the extremely stenotic graft

TABLE V CHANGES IN PRESERVED LONG AORTIC HOMOGRAFTS OF THORACIC AORTA

NUMBER OF PIGS	INCREASE IN C R (%)	INCREASE IN AORTIC LENGTH (%)	INCREASE IN GRAFT LENGTH (%)	INCREASE IN AORTIC DIAMETER (%)	INCREASE IN GRAFT DIAMETER (%)	AVERAGE DAYS GRAFT IMPLANTED	AVERAGE DAYS GRAFT PRESERVED†	THROMBOSIS (%)	STENOSIS (%)	DEGENERATION* (%)
13	84	103	16	74	14	221	96	8	39	85

*Degeneration refers to atheromatous like or calcific changes
†Preserved in light mineral oil or in Tyrode's or Ringer's homologous serum media at 4 C

In addition to a high incidence of stenosis, eleven of these 13 homografts had gross evidence of calcific degeneration Fig 1 illustrates the calcification in one of these long grafts of the thoracic aorta Calcification was found in a graft preserved for one day, as well as in a graft preserved for 413 days

4 *Preserved short aortic homografts of thoracic aorta* Eight weanling pigs had preserved short homografts implanted for 30 to 262 days during which time the animals increased their crown rump measurements an average of 90 per cent The aorta in these animals showed an average increase in length of 80 per cent whereas the grafts had an average length increment of 17 per cent A similar failure to keep pace with growth of the host tissues

was observed in the graft diameters which had an average increase of 14 per cent as compared to an average aortic diameter increase of 93 per cent One-half of the grafts in this group were classified as stenotic

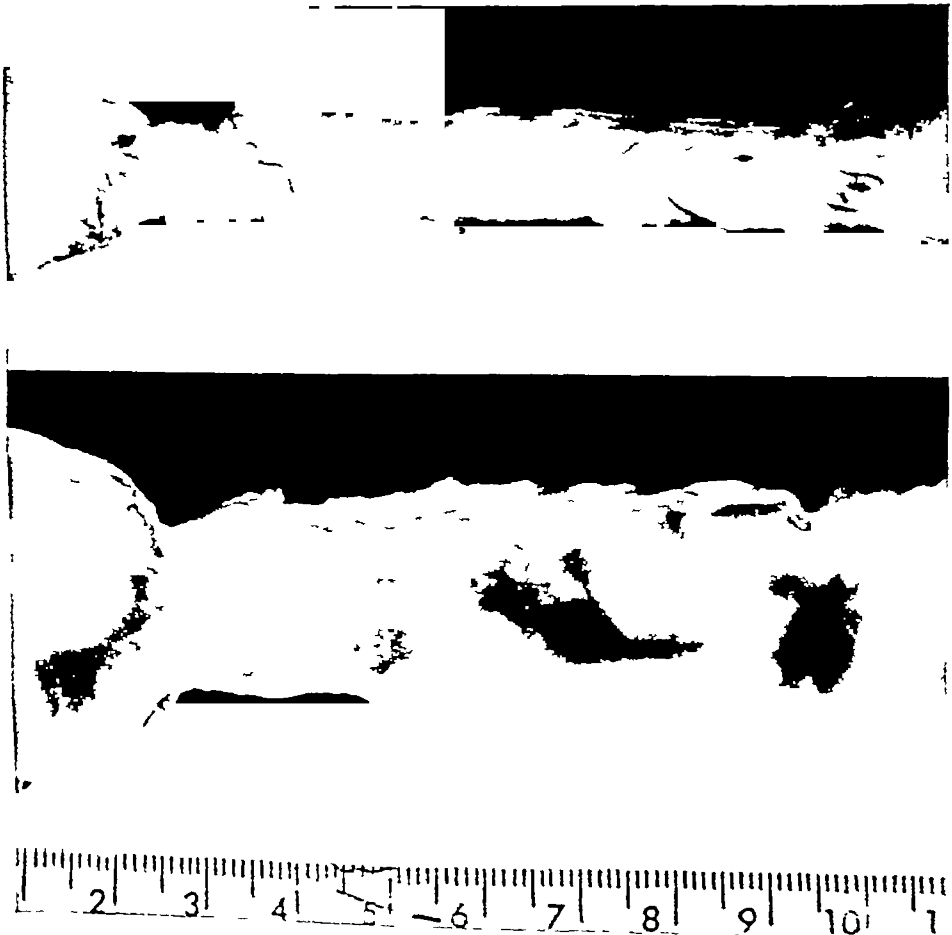

Fig 1 —Inflated and open views of a long preserved arterial homograft removed from a growing animal (Pig 133) 219 days after implantation In addition to the failure in growth of the homograft the intimal view reveals the extensive calcific degeneration throughout the graft.

One graft became occluded by thrombosis 106 days after implantation and showed massive calcification Six additional grafts in this group showed gross calcific degeneration Preservation of these grafts in sterile light mineral oil ranged from 12 to 247 days The graft which had no calcification was preserved for 243 days however it did have marked stenotic changes Table VI gives the data concerning grafts in this group

DISCUSSION

It is evident on review of the data presented in Tables I through VI that aortic homografts implanted into the thoracic aorta were less successful in terms of late complications than grafts implanted into the abdominal aorta. We are in partial agreement with Everson and Southwick[2] in their statement "All grafts which remained patent grew [*sic*] appreciably in both length and diameter." In our experiments the increase in graft size failed to keep pace in most instances with the growth of the host aorta. This was particularly true of the preserved homografts of the thoracic aorta regardless of the graft length or diameter at implantation. Although the abdominal aortic grafts in our animals showed greater increments in size than similar grafts reported by Johnson, Kirby, and Horn,[6] we agree with these authors that "normal growth" did not occur in the abdominal grafts (nor in the thoracic grafts in our series) with but two exceptions. One short preserved abdominal aortic homograft and one long fresh homograft of the thoracic aorta showed "normal growth" and complete cellular integrity 195 days and 321 days, respectively, after implantation.

TABLE VI. CHANGES IN PRESERVED SHORT AORTIC HOMOGRAFTS OF THORACIC AORTA

NUMBER OF PIGS	INCREASE IN C.R. (%)	INCREASE IN AORTIC LENGTH (%)	INCREASE IN GRAFT LENGTH (%)	INCREASE IN AORTIC DIAMETER (%)	INCREASE IN GRAFT DIAMETER (%)	AVERAGE DAYS GRAFT IMPLANTED	AVERAGE DAYS GRAFT PRESERVED†	THROMBOSIS (%)	STENOSIS (%)	DEGENERATION* (%)
8	90	80	17	93	14	229	123	12.5	50	88

*Degeneration refers to atheromatous like or calcific changes.
†Preserved in light mineral oil at 4° C.

The site of vascular graft implantation appears to be important with respect to late degenerative changes which may ultimately render the grafted segment useless. Calcific or atheromatous like degeneration was found in 11 per cent of the homografts of the abdominal aorta (combined 2 groups), while similar grafts of the thoracic aorta (combined 4 groups) had an incidence of late degeneration of 88 per cent. Calcification was noted as early as the nineteenth postoperative day (in a long fresh thoracic homograft), although Parsons, Gerbode, and Cox[9] reported an even earlier appearance of such degeneration in a homograft of the abdominal aorta in an adult dog. Calcific or atheromatous like degeneration of aortic homografts implanted into the abdominal aorta of adult dogs or growing pigs were reported by Everson and Southwick,[2] Johnson, Kirby, and Horn,[6] and Coleman, Deterling, and Parshley.[1] Calcification or atheromas were found in arterial homografts of the thoracic aorta in adult dogs by Hur and associates and Gentsch, Waters, and Glenn.[3] In our series of grafts we have under consideration the combined factors of growth, method and period of graft preservation, and graft length as they are related to the anatomic site of implantation (thorax and abdomen).

The graft length, period of graft preservation, and the method of preservation do not appear to be significantly related to the high incidence of degenera tion in thoracic homografts when compared to the abdominal aortic homografts While the grafts implanted in the thoracic aorta were generally longer than those put in the abdominal aorta, a comparison of the shorter thoracic grafts with the longer abdominal grafts indicates a similar preponderance in calcification and atheromatous-like formation in the former It is well to point out that calcification of frozen and freeze-dry aortic homografts has been noted by Coleman and associates,[1] Hui and associates,[5] and Gentsch, Waters, and Glenn[3] The factors which appear to be important though unproved in the differential behavior of abdominal and thoracic homografts are the following

1 *Difference in the Vascular Bed for the Homograft*—In contrast to the retroperitoneal tissues of the abdomen the retropleural vasculature is rather sparse The importance of this factor appears dubious since Parsons, Gerbode, and Cox[9] failed to detect any calcific changes in homografts of the thoracic aorta wrapped with silver foil in adult dogs However, the added factor of growth change may require a dynamic and adaptive tissue response which arterial homografts cannot meet

2 *Work Stress on the Aorta*—The work stress on the thoracic aorta is generally conceded to be greater than on the abdominal aorta The site of the calcium deposits in the thoracic grafts was similar to the deposits observed in human subjects having Monckeberg's medial sclerosis, a lesion which is thought to be related to work stress Gentsch and his co-workers succeeded in producing calcification in one-third of their thoracic grafts by the use of acute intravascular stress

3 *Changes in Intrathoracic Pressure During Normal Respiration*—It is not known what relationship this factor may have to the work stress on the homografted segment and the vasculature of the adjacent host tissues This factor is not present in the abdominal aortic grafts

4 *Calcium Mobilization*—The thoracic procedures required subperiosteal resection of one rib and transection of one or two additional ribs It is possible that the subsequent need for osseous restitution results in a translocation of calcium from the serum into the areas of bony injury as well as into foreign bodies which may be present namely, the aortic homografts

Aortic homografts have been used to replace segments of the thoracic aorta in human beings Gross[4] has used a homograft in 14 per cent of the patients who had a coarctation of the aorta resected The age distribution of the patients receiving these grafts is not known but follow-up studies by Gross reveal some degree of calcification in 8 per cent of the grafted cases It is unlikely that the growth increment in these patients was comparable to our experimental animals However similar rapidity of growth and relationship to work stress is conceivable in a very young child with a corrected coarctation of the aorta

The role of the "immunity response" of the host to an aortic homograft is important and presumably of equal magnitude whether implantation occurs in the thoracic or abdominal aorta or any other portion of the arterial system The ultimate development of a satisfactory vascular graft must await the determination and understanding of the host-graft immunity reaction

In the light of the data presented, the use of aortic homografts in replacing segments of the thoracic aorta in a growing subject cannot be advocated except under the most pressing circumstances since the prognosis of such grafts appears poor in experimental animals

CONCLUSIONS

1 Arterial homografts appear to function as satisfactory conduits of blood within the period of observation limits of our experiments

2 Arterial homografts of the thoracic aorta are less able to keep pace with the growth increment of the animal than are homografts of the abdominal aorta

3 In the growing animal, homografts of the thoracic aorta have a significantly greater incidence of calcific and atheromatous-like degeneration than do homografts of the abdominal aorta

4 The factors of graft length, period of graft preservation, and methods of preservation used in these experiments do not appear to influence the development of calcification and atheromatous like formation in homografts of the thoracic aorta

5 Under rare and unknown conditions, aortic homografts of the abdominal and thoracic aorta, presumably viable at implantation, may retain complete cellular integrity and behave like autografts

We wish to express our appreciation to Miss Susan Hull for the tissue sections and Mr John Newby for the photographic work

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DISCUSSION

DR ROBERT E GROSS, Boston, Mass—There may be a good deal of difference between the pig and the human being so far as fat metabolism and degenerative processes in grafts are concerned In discussing this paper I thought it might be appropriate to add to the laboratory observations some facts and data gathered from the implantation of homologous aortic grafts in human beings In a series of 330 patients whom we have operated upon for coarctation, we have deemed it necessary in 46 to insert an aortic homograft Half of the grafts had been stored in a balanced salt solution, the other half, representing our present technique, have been frozen and stored at -50° C in carbon dioxide ice Of the 46 patients with grafts, three died in the hospital of causes unrelated to the grafting, one died six months later from the eventual results of infection Whether or not infection occurred during operation or subsequent to it is impossible to say

We are interested in the study of the 42 surviving patients, observations on these are as follows 16 of these grafts have been in place for more than three years, 9 have been in place for more than four years All patients have been operated on for existing hypertension, the results in treating this have been exceedingly gratifying Two have arm pressures which have been greatly reduced from the preoperative figures but have not quite returned to normal, in the other 40 the arm pressures have dropped to completely normal levels We take this as indirect evidence that the grafts have remained patent In three patients, x ray films show a slight deposit of calcium in the graft wall In no instance has roentgen examination showed any evidence of aneurysm formation in these grafts

The first graft for reconstruction of an aortic pathway was inserted just six years ago At the present time this young man is perfectly well in every way, has normal pressures in the arms and legs, and by x ray examination has no calcification or dilatation of the graft Our observations of human beings make us very enthusiastic about the use of homografts for reconstruction of aortic pathways, when aortic ends cannot be brought together for a good primary anastomosis

A METHOD OF SUPPLEMENTING THE CORONARY CIRCULATION BY A JEJUNAL PEDICLE GRAFT

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THE average survival period of patients who have coronary artery insufficiency with angina pectoris bears eloquent testimony to the gravity of the disease Five years is the figure reported by Parker, and associates,[1] in a survey of 3,440 cases Furthermore, in patients who have had coronary infarction with or without previous or subsequent angina, the picture is even more gloomy Of 488 such cases reported by Katz and his co-workers,[2] 25 per cent were dead in two months, 50 per cent at the end of one year, and 75 per cent at the end of three years

There can be little doubt, therefore, that any investigation is worth while which has as its eventual, though perhaps distant, goal an improved prognosis for patients with coronary artery insufficiency

The object of the present paper is to review the literature briefly and to submit a preliminary report on a new surgical method which has been carried out experimentally in dogs

HISTORICAL

Fig 1 depicts in diagrammatic form some of the surgical procedures which have been attempted so far to supplement the coronary circulation in animals and man These have, as their aim, two main principles One is to establish an intercoronary anastomosis, the other to establish an extracoronary anastomosis Some of the methods, including the one to be described, would appear to stimulate both types of anastomoses

Beck and O Shaughnessy deserve much of the credit for pioneer experimental work in this field of surgery Beck and his co-workers[5-13] sutured the pectoralis major muscle to the myocardium to promote vascular adhesions, and O'Shaughnessy[3, 4] sewed the great omentum to the myocardium for the same purpose Beck reported his operation of anastomosis of a systemic artery into the coronary sinus in 1948 Fauteux[14] advocated ligature of the great coronary

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vein in association with pericoronary neurectomy and Carter and associates[15] and Moran and associates[16] have used lung and skin pedicle graft respectively to augment the blood supply to the ischemic heart

Heimbecker and Barton[30] in 1939 reported their experiments to this association in the creation of a sterile adhesive pericarditis by the injection into the pericardial cavity of sodium morrhuate, bonite, or carborundum sand In 1942 Thompson and Raisbeck[17, 18] applied this idea to patients, using talcum powder and other agents

Vineberg[19-26] has carried out careful investigations into the value of an internal mammary artery implant in coronary artery insufficiency in animals and man.

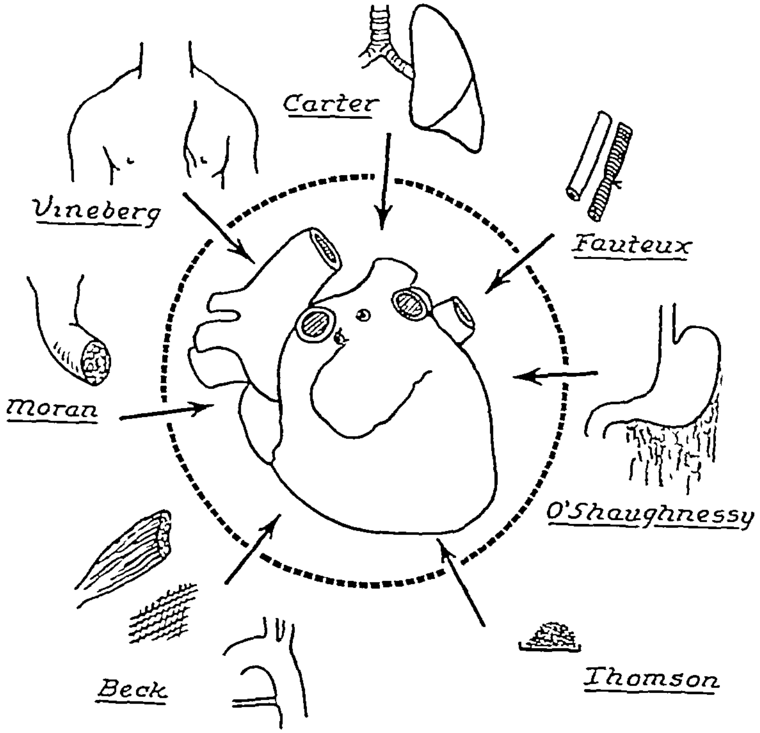

FIG. 1—Diagrammatic representation of some of the methods which have been used to supplement the coronary circulation in animals and man.

ANATOMY

Anatomical studies[27-29] have shown the presence of anastomoses between the right and left coronary arteries in animals Such anastomoses are increased by the presence of myocardial infarction or by pericardial inflammation

No matter how rich the network of blood vessels which supply the myocardium in man and animals may be the coronary arteries are essentially terminal arteries and occlusion of one or more of them by experiment or disease carries a high immediate mortality

Beck has shown experimentally in dogs that their life may virtually hang by a thread In effect, ligature of three or four small branches of the left coronary artery produces no serious myocardial change, but ligature of one small additional branch results in ventricular fibrillation and death

Such an observation supports the idea that any new contribution to the vascularity of an ischemic myocardium may tip the scales in favor of continued survival

METHODS

One hundred and eleven operations were carried out on 73 mongrel dogs *of an average weight of 15 kilograms*

Preoperative Preparation—The animals were allowed fluids only for 36 hours preoperatively and were given 300,000 units of penicillin and 1 Gm of streptomycin on the morning of operation

Anesthesia—The anesthetic induction consisted of an intravenous injection of Nembutal, 35 mg per kilogram of body weight During the operation, oxygen and ether were *administered by an intratracheal tube and positive pressure* was maintained while the chest was open

Operation—

1 *Resection of an intestinal segment* A midline supraumbilical incision was employed for the abdominal part of the operation (Fig 2, *A*) and a proximal loop of jejunum selected which could reach the cardiac apex with least tension on its vascular pedicle (Fig 2, *B*) A segment of bowel of approximately 5 to 6 inches in length was isolated from the rest of the bowel together with its intact blood supply (Fig 2, *C*) The marginal vessels at each end of this segment were ligated to avoid possible hematoma formation between the layers of its mesentery Having isolated this wedge of bowel, continuity of the remainder of the jejunum was restored by end-to end anastomosis

2 *Preparation of the graft* The isolated jejunal segment was then opened along its antimesenteric border (Fig 2, *D*) and the mucosa stripped oft, leaving a flat surface composed of serous and muscular coats of the bowel (Fig 2, *E*) During this procedure bleeding was best controlled by applying a light arterial clamp across the origin of the jejunal artery supplying the segment of bowel Following removal of the mucosa, the arterial clamp was released and the graft gently compressed by layers of gauze soaked in normal saline to ensure hemostasis After preparation of the graft, all equipment already employed was discarded

3 *Exposure of the heart and partial epicardectomy* A thoracotomy was then carried out through the left fifth interspace (Fig 2, *A*) The pericardium was opened and the myocardium sprayed with a 1 per cent procaine solution With the aid of an Allis clamp and dissecting scissors, the epicardium was removed from the anterolateral *aspect of the left ventricle (Fig 2, F)* *This last* maneuver can usually be done without damaging the superficial vessels of the

myocardium It is essential to strip the epicardium adequately so that the serosal cells, being capable of rapid regeneration may not multiply and act as a barrier to developing collateral capillary buds

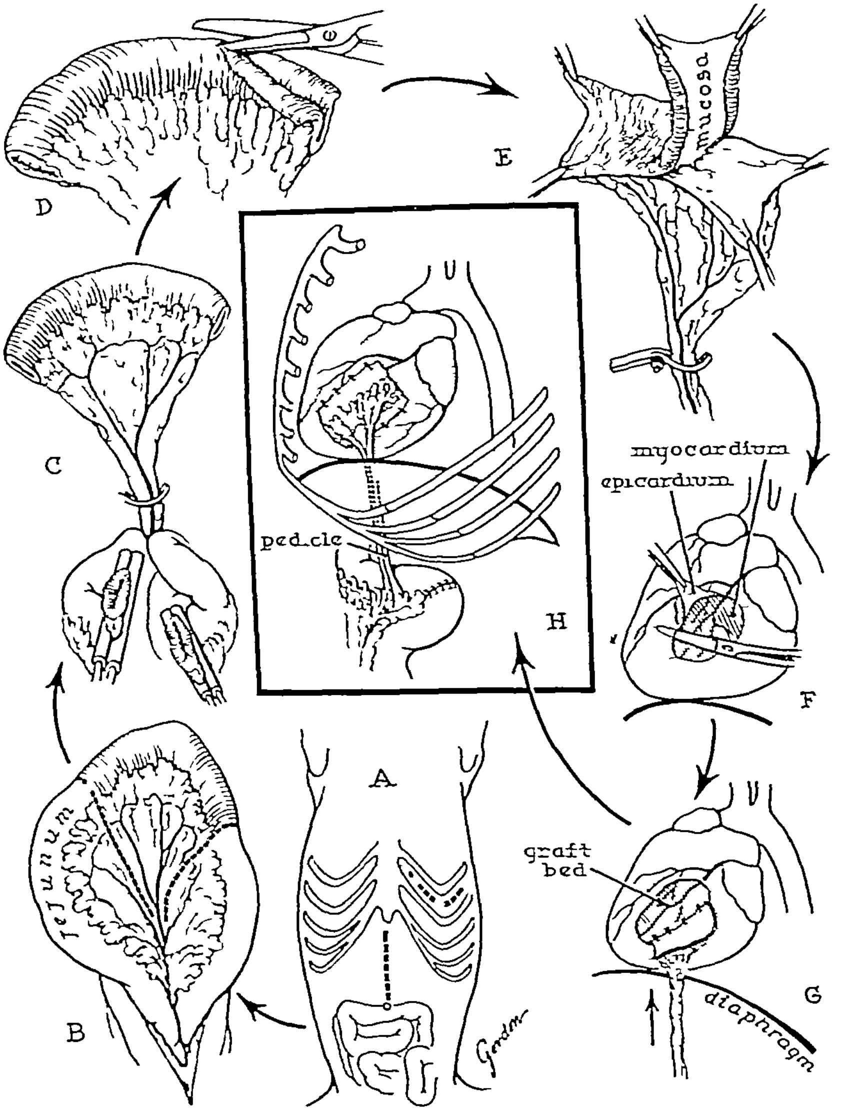

Fig .—Steps involved in the surgical technique of applying a jejunal pedicle graft to the myocardium in dogs

4 *Fixation of the jejunal graft on the myocardium* The anterior portion of the left diaphragm was incised for about 2 cm Through the opening thus made the jejunal graft was drawn into the chest and fixed to the prepared myocardial bed with 8 to 10 fine silk sutures (Fig 2 *G* and *H*) The graft should be snugly in contact with the myocardium and not stretched too tautly

and there must be no tension on the pedicle artery. The pericardial sac was left widely open. The abdomen first, and then the chest was closed in successive layers, care being taken to ensure complete re-expansion of the left lung.

OPERATIVE AND POSTOPERATIVE COMPLICATIONS

The entire operative procedure took approximately one hour and a half and was well tolerated by the animals. Supportive intravenous therapy was not employed.

There were 5 deaths encountered in a series of 35 consecutive operations. Two were due to the development of jejunal fistula at the site of end to end anastomosis of the jejunum, one was due to evisceration following infection of the abdominal wound, and one death resulted from prolonged hypoxia during anesthesia. The fifth death was due to cardiac arrest of unknown etiology. The first four deaths should all have been avoidable.

There were no cases of herniation through the diaphragm at the point where the pedicle passed from the abdomen into the chest.

INVESTIGATION TO DETERMINE THE EFFICACY OF THE JEJUNAL GRAFT

I. As a Protection Against Ligation of the Anterior Descending Branch of the Left Coronary Artery at Its Origin.—

1. In a control series of 30 normal dogs in which the anterior descending branch of the left coronary artery was ligated and divided at its origin, there were 22 deaths, a mortality of 73.3 per cent. Whether ligation and division of the artery was proximal or distal to the septal branch, it did not influence the mortality statistics in this series.

2. In 30 dogs which had had a jejunal graft carried out three months previously, similar ligation of the left coronary artery resulted in 2 deaths, a mortality of 6.9 per cent.

It is well recognized that in certain dogs the anatomical configuration at the origin of the left coronary artery varies widely. *In some dogs, for example,* a single left coronary artery was replaced by a leash of four or five vessels arising almost directly from the aorta. In such cases the protection afforded by our graft was only accepted as valid if, on final sacrifice of the animal, ligature of one or more of these anomalous vessels had produced a recognizable infarct, even though such infarcts were commonly much smaller than the infarcts produced by coronary ligation in the control dogs.

Following the sacrifice of all normal and grafted dogs, the point of ligation and division of the anterior descending branch of the left coronary artery was verified by careful dissection.

II. Electrocardiographic Tracings.—Electrocardiographic tracings were made on 12 dogs at the time of coronary ligation. Such a ligation in 3 normal dogs produced marked electrocardiographic changes consistent with myocardial infarction. *Of the 9 grafted dogs, similar ligation produced no electrocardiographic changes in 6 of them and only minimal changes in the remaining 3.*

III Size of the Infarct—In the 8 normal dogs surviving coronary ligation, subsequent investigation showed they all had large areas of infarction In an equal number of grafted dogs, 5 had only small areas of infarction and the remaining 3 had areas of involvement similar to the control series

IV Injection Studies—Two months after ligation of the coronary artery, the grafted dogs were sacrificed, injection of the pedicle artery was carried out under controlled pressure not exceeding 140 mm Hg

Radiopaque solutions were used

1 Ten per cent solution of colloidal silver iodide This solution passes freely through capillaries

2 Twenty per cent bismuth oxychloride with a particle size of not less than 20 microns This solution will only pass through arterioles of a caliber equal to or greater than 20 microns

3 Thirty-five per cent Diodrast This solution also passes freely through capillaries

By means of this injection technique, free communication between the jejunal pedicle artery and the coronary vessels was verified in 18 of the 30 grafts thus examined In an additional 4 dogs the pedicle artery and graft filled completely, but the dye failed to pass across the graft bed into the myocardial vessels In 8 cases we were unable to demonstrate patency of the pedicle artery In the 18 injections which confirmed a direct anastomoses between the jejunal artery and the coronary arteries, 6 allowed free passage of the bismuth oxychloride solution, thus denoting anastomoses between graft and myocardium of probable arteriolar dimensions In the remaining 12, silver iodide or Diodrast were the only solutions which would pass from the jejunal artery through the graft and into the coronary vessels It was thus inferred in those cases, that the anastomoses were primarily of capillary size

In those cases of successful injection, it was also noted that a richer intercoronary anastomosis had developed than was noted in the injection of the coronary vessels in normal dogs This was evidenced by the fact that the anastomosis between the right and left coronary arterial systems was much more profuse and constant than it was in our normal controls

An example of the injection of bismuth oxychloride into the coronary arteries by way of the jejunal pedicle artery is shown in Fig 3

HISTOLOGIC STUDIES

Histologic studies of the graft preparation following sacrifice of the animals confirmed the evidence already obtained by injection studies that patent vascular channels existed between the graft and the myocardium A considerable number of such channels were of arteriolar dimensions

They also demonstrated that there was no evidence of regeneration of the jejunal mucosa which had been removed some four or five months previously

Examination of the pedicle in those animals in which injection had failed revealed certain important observations In some of the cases there appeared to be quite large patent arterial channels in the pedicle which would suggest that failure to inject them was probably a technical one. In others the main jejunal artery or its first or second divisions showed a marked generalized thickening of the vessel wall in which all layers were equally involved. In a few there was a suggestion of intimal proliferation.

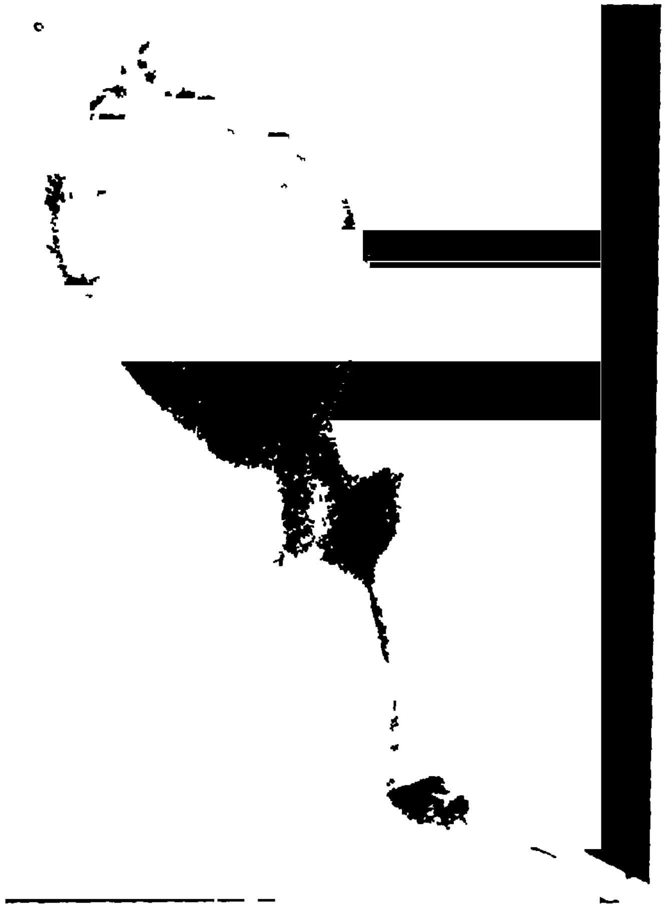

Fig. 3.—Roentgenogram showing injection of coronary arteries via the jejunal pedicle artery. The injection medium is bismuth oxychloride.

In others there appeared to be a fibrosis of the pedicle with disappearance of any recognizable vessel. These changes were only present proximal to the point where the pedicle passed through the diaphragm and suggested that constriction at this level may have played an important part in the subsequent histologic changes.

DISCUSSION

In considering the merits of any surgical procedure which might supplement the coronary circulation in animals or man certain features are of importance. The procedure should be a relatively simple performance. Any graft or implant should have a fairly wide surface of application, and preferably should be based on a systemic artery of major caliber, the diversion of which should not jeopardize any vital structure or other major artery. Ideally such a graft should stimulate intercoronary as well as extracoronary, anastomosis.

It was felt that a mucosal-free graft of jejunum based on a large jejunal artery might satisfy such criteria. With these factors in mind, the present series of experiments were devised and carried out.

The operation proved to be simple to perform, although our early operative mortality was relatively high, as has been pointed out already. Four of the five deaths should have been avoidable, even when one considers the fact that many of the animals operated on were far from ideal surgical risks.

It was found possible to create a graft surface area of almost any dimension required.

Preparation of the graft bed by removal of the epicardium is the only difficult part of the operation and it is not so difficult as it is tedious. With careful dissection using blunt thin-bladed scissors, the epicardium can be dissected off the underlying myocardium and superficial vessels. Occasionally a small vein may be ruptured and has to be sutured if local pressure will not arrest the bleeding.

The jejunal arteries upon which the graft was based were always of good size and, as was to be expected, the diversion of one such artery in no way jeopardized the adjacent jejunal vessels.

Once the theoretical criteria of a new surgical procedure appear to have been fulfilled, it is obviously of great importance to find out if such a procedure actually works in practice. Unfortunately the methods used to determine the efficiency of such an experiment in dogs leave much to be desired.

The protection afforded dogs following ligation of the anterior descending branch of the left coronary artery has been used most frequently to assess the value of any experiment which aims at supplementing the coronary circulation. It has been suggested that the results of such a procedure vary according to the point at which this artery is ligated.

It is probable that any procedure aimed at improving the coronary blood supply to the heart will give a high survival rate following ligation of the anterior descending branch of the left coronary artery if that artery be ligated too far from its origin. However, such results will be placed in their proper perspective if they are compared with the survival rates obtained in a series of normal control dogs following an exactly similar type of ligation.

The survival rate following coronary ligation in this series was 93.1 per cent in our grafted dogs and only 26.7 per cent in the normal control dogs.

The injection studies revealed patency of the jejunal artery and direct anastomosis between it and the coronary arteries in 61 per cent of the dogs, with patency of the jejunal artery and vessels of the graft in an additional

14 per cent The histologic studies suggested that failure to inject the pedicle vessels in some instances was almost certainly due to failures in technique

These injection studies further suggested that in the majority of instances, the type of anastomosis developed between the graft and the myocardium was primarily a capillary one This is to be expected from the nature of the procedure, but it is probable that the volume of blood which can pass through such a large capillary bed as is provided by a jejunal graft may equal that derived from several single small arteries

The electrocardiographic findings are of interest The immediate danger of coronary occlusion in animals and man is not primarily the damage to the myocardium per se, but to the interference with normal heart action which results Acute deaths are due to ventricular fibrillation The dangers due to actual myocardial ischemia such as myocardial rupture or aneurysm are late complications The fact that out of 9 of the grafted dogs, the electrocardiographic tracings following coronary ligation were normal in 6 and showed only minimal changes in the other 3 is probably therefore of significance, and would suggest that such a graft gives good immediate protection to coronary ligation in dogs

One additional factor should be mentioned It has been suggested that in certain grafting procedures to the heart, the blood eventually flows from the heart to the vessels of the graft and not, as is intended, in the reverse direction It was a simple procedure in these experiments to show that the flow was from jejunal artery to the myocardium, as digital occlusion of the jejunal artery at its origin obliterated all pulsations between this point and the heart, and similar occlusion of the jejunal artery at the cardiac apex failed to obliterate the jejunal pulsations in the proximal portion of the artery

Further studies are proceeding in an attempt to improve the technique of our experiments and to determine the possible cause of any failures

SUMMARY

1 A method of supplementing the coronary circulation in dogs by jejunal pedicle graft is presented

2 The operative procedure is outlined

3 The results of investigations to determine the efficacy of the graft are reported

4 The survival rate following coronary ligation in normal control dogs was 26 7 per cent and in grafted dogs 93 1 per cent

5 The possible advantages of the method of jejunal pedicle graft are discussed

It is a pleasure to acknowledge the valuable technical assistance given this project by Mr Walter Cowan and Mr Kenneth Burley

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DISCUSSION

DR JOHN R FOX, JR, Memphis, Tenn —Because of the unsettled status of various cardiopexy procedures, we at Kennedy Hospital have tried to work out some of the principles involved The amount of anastomosis with the anterior descending coronary artery is rather variable There is usually a large branch at the apex and often one or more proximal branches communicating from the circumflex branch of the left coronary artery

This slide shows the sites of ligation employed in dog experiments The communicating branches are ligated at whatever preliminary operation is done and the anterior descending artery as a subsequent procedure In this way a constant area of infarction has been obtained

With ligation alone, a 70 per cent mortality rate has been encountered With talcum powder used to create an adhesive pericarditis, the mortality following ligation dropped to 10 per cent, although the infarcted areas have been nearly as large The amount of new circulation induced by this method has not been impressive, but there has been much less bulging of the ventricular wall after ligation Perhaps the adherent pericardium serves as a splint, preventing blowouts and enabling efficient pumping to continue

Because of the size and proximity of the left gastric vessels, various cardiopexies have been done with pedicles employing these vessels, ranging from full thickness grafts denuded of mucosa to implantation of the artery branches themselves into the myocardium The most successful method has been to free up a split layer of gastric wall by water injection and then to suture this to the left ventricular wall, which is first roughened and powdered with talcum powder All dogs so prepared have survived coronary ligation and have shown very minimal infarction

CONTROLLED CROSS CIRCULATION FOR OPEN INTRACARDIAC SURGERY

Physiologic Studies and Results of Creation and Closure of Ventricular Septal Defects

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THE curative surgical attack on a number of intracardiac lesions has been stymied by the lack of a safe and satisfactory method for operating in a leisurely fashion under direct vision within the open chambers of the heart. Appreciating the historic lesson that the solution of many problems in medicine has ultimately been simple and, in most cases, obvious, once sufficient knowledge has been brought to bear upon the problem, we began work several years ago to look for a simple, safe, and efficient method for open intracardiac surgery.

The first step toward this goal was the definition of the tolerance of the canine heart and other organs to complete inflow stasis at normal temperatures.[4] The second major step was the demonstration by Andreasen and Watson[1] and Cohen and Lillehei[5] that dogs were able to survive long periods of complete vena caval occlusion without discernible injury if the flow through the azygos vein into the heart was unimpeded. Cohen then measured the azygos flow in terms of c.c./min./kg. of body weight. He found this azygos flow to be 8 to 14 c.c./min./kg. of body weight or slightly less than 10 per cent of the generally accepted basal cardiac output. Careful physiologic studies of these dogs uniformly surviving 30- to 60-minute periods on their azygos flow, indicated that under these conditions the dog's body became tremendously more efficient in its utilization of oxygen.

The significance of these studies in reference to cardiac by-pass was obvious, and the next step was to acquire a simple and efficient pump† capable of pumping blood in two circuits simultaneously and in exactly equal amounts.

Modification of the mode of oxygenation of blood was then approached. It was apparent to us that the intricacies of this process could be avoided if normal lung tissue could be employed for this purpose. Also existing extracorporeal oxygenators inevitably removed platelets and fibrinogen so that postoperative clotting defects were likely. Likewise, in most mechanical oxy-

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genators the second most important function of the lungs has been ignored, namely, the filtration from the blood of harmful particulate matter[3] including bacteria. Finally, a substantial amount of physiologic evidence has suggested that lung tissue has certain somewhat more obscure but, quite possibly, important functions in reference to revitalizing the blood that circulates through them.

A very satisfactory solution to the oxygenation problem was developed experimentally by utilizing a lobe of the dog's own lung.[6] However, this method had the technical disadvantages of delicate cannulations and the necessity for keeping the lungs inflated during the intracardiac procedure, thus interfering with access to the heart.

In an attempt to eliminate these shortcomings of the autogenous lobe experiments, we turned to the use of a donor circulation to oxygenate and revitalize the blood and utilized the same pump to control accurately the exchange of blood which had been the major pitfall of this method in the hands of others.[2, 8, 9] By this method of controlled cross circulation there was interposed between donor and recipient a single pump which circulates equal amounts of oxygenated blood from the donor's artery to the recipient's aorta, and venous blood from the recipient's cavae to the donor's venous circulation.

METHOD

Healthy mongrel dogs weighing from 9 to 18 kg. were used as recipients, while the donors ranged from 15 to 32 kg. in weight. Preoperatively, each received 4 to 5 mg. of morphine per kilogram and 1/100 grain atropine. Pentothal sodium (2½ per cent) intravenously was used as the anesthetic agent. Each animal had an endotracheal tube inserted. The recipient was ventilated by a mechanical respirator while his chest was opened. During the interval of cardiac by-pass, the recipient's lungs were collapsed, and the donor was ventilated with 100 per cent oxygen.

The donor was placed on his back on a table (Fig. 1, *A*), the foot of which was at right angles to the head of the recipient (Fig. 1, *B*), who was positioned preparatory for a right thoracotomy. The femoral artery and vein of the donor were isolated and cannulated with plastic 12 Fr. catheters (Fig. 1, *AA*), following which he was heparinized (0.75 mg./lb.). The right common carotid artery and the external jugular vein of the recipient were isolated and the carotid cannula inserted and passed 5 to 6 cm. toward the aorta (Fig. 1, *B* and *BB*). A thoracotomy was then made through the right fifth interspace of the recipient, the azygos vein was ligated, and umbilical tapes were passed around the superior and inferior venae cavae at their entrance into the heart (Fig. 1, *BB*). Next, the pericardium was incised longitudinally just anterior to the phrenic nerve, and the anterior margin of the pericardium was sutured to the wound margin to elevate the heart in sling fashion into the operative field. The recipient was then given 0.75 mg. heparin per kilogram intravenously, and the jugular vein cannulization was made. This cannula had accessory holes cut along its shaft at a distance from the tip greater than the space between the vena caval tapes in the animal concerned. As this cannula was passed down the jugular into the caval system, the tip was guided into the inferior vena cava and positioned so that the holes in the catheter were well above and below the superior and inferior vena caval occluding tapes, respectively (Fig. 1, *BB*).

With these animal preparations completed, the final step was the connection of the pump (Fig. 1, *C*) to the plastic cannulae. The desired flow was determined on the basis of the recipient's preoperative weight and the azygos flow factor. The pump was set to deliver this amount in each circuit. One of the afferent limbs of the pump tubing was connected to the donor's femoral artery cannula and the pump was turned on momentarily to fill this half of the extracorporeal circuit. The efferent end of this circuit was then connected to the recipient's carotid artery cannula, thus completing the arterial circuit Next the remaining afferent limb of the pump was attached to the recipient's caval cannula, the pump was again run for a short interval to fill this portion of the circuit, whereupon the remaining efferent limb was connected to the femoral vein cannula of the donor The total

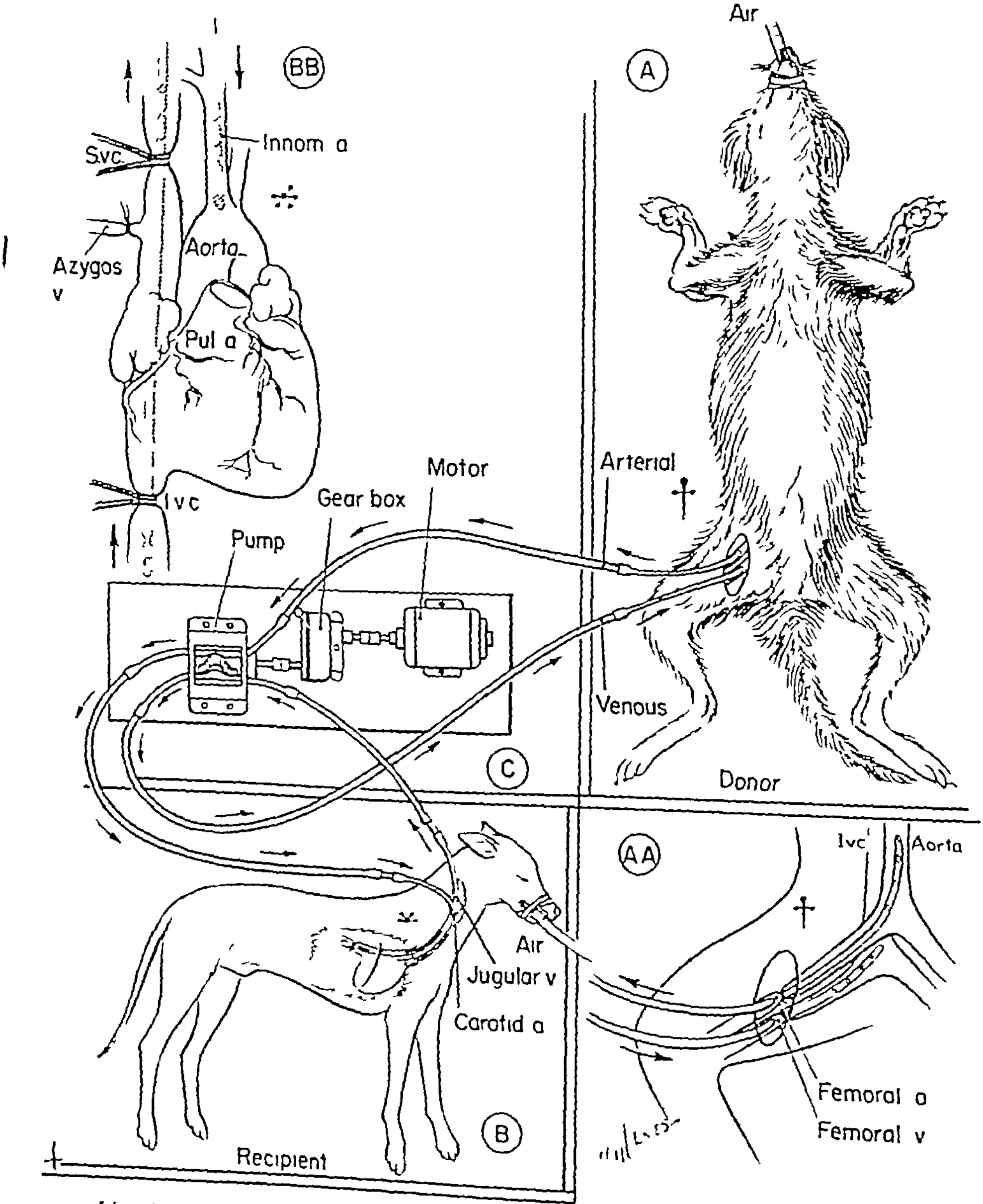

Fig 1.—Controlled cross-circulation. *A* Donor animal showing site of arterial and venous cannulations *AA* Close-up of the femoral arterial and venous catheters positioned with their tips in the aorta and vena cava respectively *B* Recipient animal (patient) demonstrating the position of the arterial cannula in the carotid artery directed toward the aorta, and the venous cannula inserted through jugular vein and positioned so that venous blood is simultaneously removed from both the superior and the inferior venae cavae (refer to close-up *BB*) *C* The pump The entire system has only two controls one is the speed changer which couples the motor to the pump and which is set prior to starting the pump and the other is a switch to turn the motor on and off

quantity of blood required to fill these two circuits was approximately 120 c c With the arterial and venous circuits connected, the pump was turned on, the venae cavae occluded and the right ventricle opened widely through either a vertical or a horizontal cardiotomy A soft plastic suction tip was then inserted well up into the right ventricular outflow tract to remove coronary sinus and thebesian blood In those animals where a septal defect was made, a cork borer or a No 11 Bard Parker knife was inserted through the upper portion of the ventricular septum Immediately following this, a second plastic sucking catheter was passed through the defect into the left ventricle where it remained during placement of the septal closure sutures Just before these were tied, the septal sucker was replaced by a metal cannula which injected 5 per cent glucose into the left ventricle for the purpose of air displacement This flow continued until the first septal suture was tied, whereupon the cannula was withdrawn The remaining sutures were tied and cut, repair of the cardiotomy was done by a continuous full thickness silk suture During closure of the ventricular cardiotomy no attempt was made to remove coronary sinus blood with resultant gradual filling of the right ventricular cavity As closure of the cardiotomy was completed the recipient was put back on the mechanical respirator and the inferior vena caval tape was released gradually and carefully to avoid dilatation of the right auricle After this the superior vena cava was similarly released slowly and the pump turned off The chest was then closed and the cannulae were removed from the patient and donor with ligation of all vessels concerned The recipient was usually given 50 mg of protamine sulfate and 500 mg of calcium intravenously at this time Postoperatively all animals were given 600,000 units of penicillin intravenously once daily for 4 to 5 days, and 300,000 units procaine penicillin and 0 5 Gm streptomycin intramuscularly for one week

In those animals in which physiologic studies were performed during complete cardiac by pass the ventricular cardiotomy was not performed *

RESULTS

The results of these studies involving cross circulation may be conveniently subdivided into two categories

Group 1 the study group consisted of 31 dogs (17 as recipients and 14 as donors 3 serving as donors twice) utilized for certain physiologic and metabolic observations to ascertain efficiency of this method for maintenance of complete cardiac by-pass for thirty minutes As mentioned above, cardiotomies were not performed in this group of animals

Group 2, the operative group consisted of 67 dogs (37 as recipients and 30 as donors 7 serving twice) in which right ventricular cardiotomies with the creation and then immediate closure of a high ventricular septal defect was performed With the exception of plasma hemoglobin determinations no physiologic studies were performed on these animals These operations were done with clean but not sterile technique, their principle objective was to determine the tolerance of the myocardium (and conduction system) to cardiotomies and interventricular septal suture at blood flow rates consisting of various multiples (1 to 5 5† times) of the azygos flow

PHYSIOLOGIC OBSERVATIONS

These seventeen animals in the study group were further subdivided into three categories upon the basis of the rate of blood flow used to perfuse the whole body of the recipient during the period of total cardiac by-pass

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Since the lungs of the recipient were completely collapsed during the entire period of cardiac by-pass the internal recirculation of the coronary sinus flow contributed nothing to the animals survival in these study animals

†5 5 times the azygos flow is approximately 30 to 50 per cent of the usually accepted basal cardiac output

Group A_1 represents the dogs in which the pump was set to deliver an amount of blood exactly equal to the recipient's azygos flow* as calculated from the previous measurements[2] upon azygos flow in relationship to body weight.

Group A_2 represents dogs who received a rate of blood flow to the recipient of twice A_1.

Group A_3 represents dogs who received a rate of blood flow three times A_1.

There were two animals in Group A_1, seven in Group A_2, and eight in Group A_3. Group A_1 was limited to such a small number of animals because the results obtained seemed to closely parallel those of the autogenous lobe study[7] in which flows of the same magnitude were used. Further, the experiments involving creation and closure of ventricular septal defects indicated that the heart tolerated trauma poorly while receiving flows of A_1 magnitude, so that it did not seem practical to expand this group.

TABLE I BLOOD PRESSURE ALTERATIONS OF THE RECIPIENT DURING THIRTY MINUTES OF CONTROLLED CROSS CIRCULATION (MM. HG)*

RATE OF FLOW	BEFORE	HIGH DURING CIRCULATION	LOW DURING CIRCULATION	AFTER
A_2 (Azygos) (x2)	98	48	20	95
A_3 (Azygos) (x3)	115	80	61	100

*Average pressures for 7 dogs in Group A_2 and 8 dogs in Group A_3.

Blood Pressure.—The recipient's mean femoral arterial blood pressure as recorded by mercury manometer was observed immediately before, during, and within two minutes after shutting off the pump at the conclusion of thirty minutes of total cardiac by-pass. For the two A_1 animals the results were similar to those observed previously in the autogenous lobe study ranging between 30 to 40 mm. Hg during by-pass with a prompt return to control levels after conclusion of the by-pass. The group A_2 animals had a control blood pressure of 98 mm. Hg with a mean high† of 48 mm. Hg and a mean low‡ of 20 mm. Hg. The return to control levels was prompt.

The A_3 group had a less severe drop in systemic blood pressure with a mean high of 80 mm. Hg and a mean low of 61 mm. Hg during the cross-circulation period. These data, in respect to the blood pressure changes, are summarized in Table I.

Hemolysis.—The degree of hemolysis occurring during these cross circulation studies was measured by plasma hemoglobin determinations done just prior to starting the pump and one half hour after the completion of the 30 minute run. Although the plasma hemoglobin levels were quite variable, it is evident from the data depicted in Table II that some red cell destruction does occur and as might be anticipated, tended to increase in proportion to the increase in flow rate. However, in light of the well-known fragility of canine red cells, the maximum values observed did not appear excessive.

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*Eight to 14 c.c./kg. body weight/minute.

†Represents the average of the highest recording that was maintained for at least five minutes during the time of total cardiac by-pass.

‡Represents the mean of the lowest levels attained at any time during the by-pass period.

TABLE II. PLASMA HEMOGLOBIN DETERMINATIONS AFTER THIRTY MINUTES OF CONTROLLED CROSS CIRCULATION (MG. PER CENT)

RATE OF FLOW	NO. DOGS	RECIPIENT		DONOR	
		BEFORE	AFTER	BEFORE	AFTER
A_1 (Azygos)	2	31.5	46.7	—	—
A_2 (Azygos) (x2)	7	30.8	49.9	27.8	50.6
A_3 (Azygos) (x3)	8	39.1	128.4	35.7	142.1

Hemoglobin and Hematocrit Values.—Hematocrit and hemoglobin determinations were made just prior to and just after the conclusion of the period of inflow stasis on all recipients and on all donors in Groups A_2 and A_3 (Table III). In every instance there was a rise in the hemoglobin content ranging from 2 to 3 Gm. per cent with a corresponding rise in hematocrit. This hemoconcentration was transient, and within two hours postoperatively, all values had returned to the preoperative levels.

Blood Oxygen and Carbon Dioxide Contents.—Arterial, venous, and cerebral* arterial oxygen determinations were made on all recipients before the onset and just prior to the end of 30 minutes of total cardiac by-pass. In each of the three groups it may be noted (Table III) that there was a mean increase of from 2.5 to over 5 volume per cent in the 30-minute arterial oxygen content over that observed in the control state. This rise appears to parallel the hemoconcentration observed.

On the other hand, the venous samples drawn near the end of 30 minutes of total by-pass showed a marked drop in their oxygen content from control levels of 10 to 14 volumes per cent to 3 to 6 volumes per cent. This desaturation was maximum in the A_1 group of animals where the mean 30 minute venous oxygen content was only 3.09 volumes per cent, while in Group A_2 it was 4.50 volumes per cent, and in Group A_3 it was 6.40 volumes per cent. This variation in groups no doubt reflects the difference in perfusion rates with slower flows permitting more complete utilization of available oxygen by the tissues. The recipients' cerebral arterial samples had slightly smaller oxygen contents than their systemic arterial samples, but showed the same alterations as did the other arterial samples, namely, an increase during the perfusion period. These lower contents were explained by the fact that these samples were taken from the distal end of the carotid used for cannulation and therefore came from the cerebral collateral circulation.

The venous carbon dioxide contents shown in Table III merely demonstrate an expected increase in the carbon dioxide content of the venous blood returning to the donor for oxygenation.

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*Samples drawn from distal (cerebral) end of the carotid artery used for cannulization.

TABLE III. CHANGES OCCURRING IN HEMOGLOBIN CONCENTRATION, OXYGEN CONTENT, PH AND VENOUS CO₂ CONTENT AFTER THIRTY MINUTES CONTROLLED CROSS CIRCULATION (MEAN VALUES*)

	HEMOGLOBIN (GM %)				OXYGEN CONTENTS (VOL %)						PH		CO_2 (VOL %)	
	RECIPIENT		DONOR		ARTERIAL		VENOUS		CEREBRAL		ARTERIAL		VENOUS	
RATE OF FLOW	BEFORE	AFTER	BEFORE	AFTER	BEFORE†	AFTER‡	BEFORE†	AFTER‡	BEFORE†	AFTER‡	BEFORE§	AFTER‡	BEFORE†	AFTER‡
A_1 (Azygos)	14.0	15.9	—	—	19.65	21.21	14.14	3.09	16.00	17.25	7.18	7.26	17.20	52.09
A_2 (Azygos) (×2)	14.0	16.7	14.5	16.8	19.87	23.42	10.87	4.50	19.41	21.57	7.51 7.37	7.27	19.22	51.24
A_3 (Azygos) (×3)	14.5	17.5	15.2	16.7	17.85	23.10	11.66	6.10	18.20	22.19	7.53 7.28	7.17	17.80	50.32

*Number of animals constituting mean is same as Table I for A_2 and A_3. There were only two animals in A_1.

†The "before" samples were drawn from the recipient's arterial or venous cannulae as indicated immediately prior to the start of the total cardiac by-pass.

‡The "after" samples were drawn from the arterial or venous limb respectively as indicated of the extracorporeal circulation just prior to the conclusion of the 30 minute period of total cardiac by-pass.

§The top figure in each instance represents the arterial pH of the recipient and the lower represents that of the donor dog.

Arterial pH.—Arterial blood samples were drawn (before perfusion) for pH determinations on all animals (with the exception of the two donors in Group A_1). The 30 minute samples were drawn directly from the arterial portion of the extracorporeal circuit with the pump running, and were interpreted as representing the pH of both animals, since complete mixing of the bloods had occurred several times over by this time. It is interesting to note that the mean control pH levels in the recipients were slightly on the alkalotic side, while the donors were slightly acidotic. This difference, we believe, resulted from the fact that the recipients were artificially ventilated by a mechanical respirator during the preparatory phases, while the donors were allowed to breathe on their own during this phase. This discrepancy has been eliminated in subsequent studies.

The pH values in the postperfusion samples showed a consistent fall from the control values (Table III). The decline in pH was greater than had been anticipated, for it was expected that the presence of the normally functioning lungs, liver, and kidney of the donor in the extracorporeal circuit would reduce the magnitude of this change as compared with the degree of acidosis observed in the autogenous lobe experiments.[7] However, it may well be that, had the donor been properly ventilated throughout the entire procedure to prevent this initial acidosis, this drop in pH might have been considerably less.

In the course of these studies in which total cardiac by-pass was maintained for 30 minutes, there were no deaths among the donors; 3 of the 17 recipient study animals died 24 hours after surgery. In all three of these animals death was due to a preventable complication (two of postoperative hemorrhage into the chest, and one of atelectasis with pneumothorax).

CREATION AND CLOSURE OF VENTRICULAR SEPTAL DEFECTS BY SUTURE

In this second (or operative) group of animals there were 37 dogs in which high interventricular septal defects were created and closed as described. In 23 of these dogs the rate of perfusion during cardiac by-pass was less than three times the calculated azygos flow (based on body weight). In these 23 animals there were 15 deaths and 8 survivors. Moreover, 2 of the 8 survivors had central nervous damage. Ventricular fibrillation occurring in association with an atonic myocardium was the most frequent cause of death in this group.

In 14 dogs the identical operative procedure was carried out with a perfusion rate of 3 to 5½ times the calculated azygos flow. In these dogs there were 10 (72 per cent) survivors (none with cerebral damage) and 4 deaths. Ventricular fibrillation was much less frequent with these higher rates of blood flow and in those dogs in which it did occur the better myocardial tone made successful defibrillation the rule. Heart block was observed only once in either group.

DISCUSSION

From study of the data presented there are several observations worthy of note in regard to this method of controlled cross circulation utilizing a reduced rate of blood flow for the systemic perfusion of the recipient. The recipients as a group developed a moderate hemoconcentration, maximal arterial hemoglobin saturation and marked venous desaturation with a consequent increase in the coefficient of oxygen utilization. When these changes occurred to a moderate degree, they appeared to be beneficial, as has been previously discussed.[6, 7] Moreover, these alterations were not significantly different in magnitude from those observed in the autogenous lobe studies.[7] The acidosis observed in these cross-circulation studies was also similar to that found in the earlier studies.[7] As noted at that time, we have considered a moderate degree of acidosis a desirable feature inasmuch as it augments the dissociation of oxyhemoglobin. In these present studies it is quite possible that the degree of acidosis noted was in part due to neglect of adequate ventilation of the donor during the preparatory stages of the operation.

Another noteworthy observation was the apparent tolerance of the recipient to prolonged periods of hypotension during the cardiac by-pass and the rapid return to normal, demonstrated by these animals when venous inflow was restored to the heart. This observation would suggest that there may be a fundamental difference between hypotension due entirely to a small but well-oxygenated quantity of arterial blood circulating (as is the case in the recipient in the cross circulation setup) and the profoundly deleterious effects of prolonged periods of hypotension due to low cardiac output occasioned by trauma or blood loss.

The results of the operative series indicated in a striking manner the effects that an increased perfusion rate had upon the tolerance of the heart to surgical trauma. The manner in which the heart tolerated septal incision and suture in the group of animals perfused at flow rates 3 to 5½ times the azygos level indicated that the recipient's blood perfusion rate during total cardiac by-pass can be substantially reduced in quantity without significantly reducing the tolerance of the myocardium to surgical manipulation. The several compensatory factors responsible for this favorable state of affairs have been previously discussed.[7] One of the most important of these protective factors related to the myocardium itself is the fact that once the heart has been relieved of its work load by the pump its oxygen consumption is drastically reduced. Thus maintenance of more coronary flow than is needed serves no useful purpose and is actually detrimental because, if the heart is opened blood loss will be increased and the surgeons' vision obscured. Other advantages of perfusing the body with less than the generally accepted basal cardiac output are the greater simplicity and consequent safety possible. Therefore it becomes of the utmost importance to define objectively the optimum level to which total body flow may be quantitatively reduced without untoward sequelae. The operative results suggest that this optimum level is somewhere between 30 and 50 per cent of the basal cardiac output. Obviously, further physiologic studies are required to determine this important information precisely.

The dangers to the donor in controlled cross circulation appear to be negligible if due attention is paid to the canine blood groups[10] and to air embolism. The latter has occurred only when the recipient's vena caval catheter was improperly placed so that blood was not aspirated simultaneously from both caval systems or improperly placed so that one of the openings lay within the occluding tapes and air was aspirated when the heart was opened Likewise, it is important that the donor's arterial catheter tip be in the aorta to prevent the openings being occluded by a collapsed vessel wall

The temporary physiologic effects of controlled cross circulation upon the donor are similar to an arteriovenous fistula

SUMMARY AND CONCLUSIONS

1 Controlled cross circulation consists of the reciprocal transfer of blood from the arterial system of the donor to the arterial circulation of the recipient and from the venous system of the recipient to the veins of the donor

2 The use of a single pump capable of pumping two circuits simultaneously and in equal amounts has served to control this interchange of blood efficiently and safely

3 With two animals linked together by means of controlled cross circulation, the recipient's cardiac inflow was completely occluded for 30 minutes in 17 dogs in which physiologic studies were made and in 37 other recipient animals in which a right ventricular cardiotomy with creation and closure by suture of a defect in the interventricular septum was performed

4 In the 17 recipient animals comprising the study group, the circulatory flow during their period of total cardiac by-pass was reduced substantially below their normal basal cardiac output

5 No harmful effects were observed in the recipients following total cardiac by-pass at these reduced rates of flow Recovery was uniformly prompt and without sequelae

6 Physiologic observations upon blood pressure, hemolysis, hemoconcentration, acid-base balance, venous carbon dioxide content, and arterial and venous oxygen contents were made in these animals During the by-pass period at reduced rates of blood flow, the recipients' arterial oxygen content rises and the venous oxygen content falls substantially, resulting in a considerable increase in the recipients' coefficient of oxygen utilization These changes are also associated with an acidosis of moderate degree The implications of these various observations are discussed

7 In the 37 recipient dogs comprising those in which ventricular septal defects were made and closed it was found that in the 23 dogs in whom the flow rate during the operative procedure was maintained at the azygos flow level (8 to 14 c c /min /kg body weight) or up to three times this level, the operative mortality was high (65 per cent) due to the frequent occurrence of ventricular fibrillation associated with an atonic myocardium When the flow rate was maintained at from 3 to 5½ times this azygos flow level, ventricular cardiotomy with creation and suture of a septal defect was well tolerated (72 per cent survivors)

8 Thus it was evident that the heart can satisfactorily withstand surgical manipulation when provided with well-oxygenated arterial blood in vol

times much less than the normal basal cardiac output The optimum level to which this flow may be reduced without sacrificing safety needs more precise definition

9 Controlled cross circulation was found to be a very safe procedure for the donors The donors' hazards were confined to easily preventable complications such as blood incompatibility or air embolism due to faulty cannulations

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DISCUSSION

DR E CONVERSE PEIRCE II, Knoxville, Tenn —I should like to congratulate Dr Warden and the other members of his group on successful human application of cross circulation, and would like to show a short movie illustrating cross circulation applied to by passing the left side of the heart to enable one to work on the mitral valve This was worked on dogs by Dr James Southworth and myself about three years ago In this preparation we utilized a circulation that takes the blood from the recipient's left pulmonary artery to the femoral veins on the donor and returns it from the femoral arteries to the left subclavian artery

(Film) The shunting tubes are in place and we are about to open the heart which will be relatively bloodless This procedure is done without a pump A pump is necessary in order to by pass the entire heart but not necessary to by pass the left heart One can see into the mouth of the auricle you will shortly see the mitral valve The valve leaflets are present here and on slow motion you can see how they are pushed outward by blood collecting in the ventricle During injection of a sclerosing material into the mitral valve, fibrillation occurs Subsequently we used fibrillation deliberately to still the heart It is well tolerated under cross circulation and it makes it much easier to work inside the heart

The heart has now been resutured and a single electric shock produces reversion, indicating that it was adequately oxygenated during the cross circulation despite fibrillation of about 30 minutes

DR C WALTON LILLEHEI Minneapolis, Minn —This method of controlled cross circulation developed in our experimental laboratory seemed to us to approach in many aspects our goal of an ideal method for open intracardiac surgery in that it was simple in con cept and application, remarkably safe, inexpensive, widely applicable, and most important of all, allowed the surgeon prolonged time within the open heart in a relatively dry field

In the three clinical cases of closure of interventricular septal defects which I shall mention briefly today, we have been joined by our colleague at the University of Minnesota, Dr Richard L Varco, who has been an early and enthusiastic advocate of the possibilities of this method

(Slide) This diagram illustrates the method of linking together by plastic catheters of the donor and patient in the clinical cases, and is almost identical to that utilized in the experimental work In all three of the clinical cases the donor venous catheter has been inserted through the saphenous vein with the tip positioned in the iliac vein or inferior vena cava The arterial cannula of the donor has been put in through a small transverse nick in the superficial femoral artery with its multiple holed tip positioned in the abdominal aorta so that there will be no possibility of obstruction during perfusion by collapse of the vessel wall In the patient the venae cavae cannula is inserted from the neck by means of a short supraclavicular incision exposing the jugular vein The tip of this catheter lies in the inferior vena cava, and holes cut along the shaft are positioned to lie in the superior vena cava Thus this cannula draws blood from both caval systems during the cardiac by pass The patient's arterial catheter is inserted through the right subclavian artery with the tip directed toward the aorta The only vessel utilized in these cannulations which requires repair is the small nick in the donor's superficial femoral artery which has been routinely repaired by a few stitches of 6 0 silk

The pump model utilized by us in all the dog and human patients is simple, efficient and widely utilized in industry The same pump covers the range from small dogs to adult human beings The maximum plasma hemoglobin observed in the three clinical cases has been 12 mg per cent The entire system has only two controls one is a speed changer which is set ahead of time by direct calibration at the rate desired, the other is a switch to turn the electric motor on and off The blood in the extracorporeal circulation (volume about 100 c c) never leaves the short plastic tubes, so that very little heparin is needed Postoperative bleeding, moreover, has not occurred in the clinical patients probably because fibrinogen and platelets are not removed from the blood by this method Since the plastic tubing and catheters are disposable, sterility is not a problem

All these cases have been operated upon at normal body temperature The azygos flow concept indicated to us that attempts to pump the full amounts of the so called resting or basal cardiac output were completely unnecessary and actually detrimental for a number of reasons, of which one is that the coronary sinus blood loss will be greatly increased thereby

The problem of working within the heart having been thus solved, the next problem was technical in nature, viz, how best to close interventricular septal defects Most of these defects lie in a characteristic position high in the septum in close juxtaposition to the aortic, tricuspid, and pulmonary valves Careful study of fresh autopsy specimens over the past three to four years had demonstrated to us that even the largest interventricular septal defects could easily be closed without tension by sutures placed under direct vision with the heart emptied of blood This method of closure by direct suture of the opposing edges has been successfully utilized in all three of our clinical cases Despite reports to the contrary we have found both experimentally and clinically that the conduction system of the heart has presented no problem in the placement of stitches in the ventricular septum as long as the temperature and oxygenation of the myocardium are normal None of our patients' hearts has fibrillated or shown any appreciable abnormality of rhythm before, during, or after by pass No drugs, other than digitalis, have been used

The exposure is through a long right ventricular cardiotomy We have operated upon three patients The first was a boy 1 year old, who had been in the hospital for the preceding 9 months because of continual cardiac failure and pneumonia His ventricle was open for 12½ minutes during closure of the defect The operative procedure went very well, however he died on the eleventh postoperative day because of a tracheobronchitis and pneumonia This was quite a disappointment but we were convinced of the soundness of the method. The next week we did the following two cases, both of which have been successful. In the second case we had some technical difficulties with exposure of the defect (which have since been solved) which required the ventricle to be open for 24 minutes. This boy has convalesced satisfactorily in spite of some postoperative pneumonia and the shunt is closed. This case illustrates graphically the reserve of time that the surgeon has at his disposal with this method. The third case, a 5-year-old girl, had the largest defect of all but probably because of increased experience the operation went smoothly. Only ten minutes in the open heart was required to close the defect. The previous loud systolic murmur and thrill of the third patient was completely gone.

Almost all blood relatives will have compatible blood and in all these children we have had our choice of using either the mother or the father as the donor. None of the donors to date has experienced any untoward effects; they have all been discharged from the hospital 24 to 36 hours postperfusion with good arterial pulses in the utilized leg.

Since the original presentation of this report seven additional patients have had direct vision intracardiac procedures performed by this method. Four of these patients have had closure of ventricular septal defects, three successfully. The death occurred four days postoperatively in an infant with only one functioning lung. Two patients have had closure of an atrioventricularis communis. The first patient was a failure because of improper technique of closure; in the second patient complete closure has been successful. One patient has had direct vision resection of an isolated infundibular pulmonic stenosis performed successfully. None of these donors has suffered any ill effects.

DR. JOHN H. GIBBON, JR., Philadelphia, Pa.—We are still convinced that it is preferable to perform operations involving an open cardiotomy by some procedure which does not involve another healthy person. There must be some risk to the donor in a cross circulation.

(Slide) This is a photograph taken at operation of the opened right ventricle of a 28-year-old man with an interventricular septal defect. While the heart was open, the cardiorespiratory functions were maintained by an extracorporeal blood circuit for 26 minutes while the defect was closed.

(Slide) This shows the defect closed by four interrupted silk sutures. This man went through the operation very well, but he died five hours later.

One year ago we closed a large interatrial septal defect through an open cardiotomy while the cardiorespiratory functions were maintained for 26 minutes by the extracorporeal blood circuit. (Slide) This photograph of the 18-year-old girl was made three months later when she returned to the hospital for cardiac catheterization which demonstrated that the defect was completely closed. The patient is perfectly well one year after the operation. There are no cardiac murmurs and her heart has decreased in size. I still believe that the ideal method of performing an open cardiotomy is the maintenance of the cardiorespiratory functions by an extracorporeal mechanical blood circuit with the patient at normal body temperature.

DR. A. I. LOCKWOOD, Toronto, Ontario.—In 1924 I pointed out that I thought anything was possible in thoracic surgery given sufficient blood, proper diagnosis, and a select anesthesia. I still do not think we have more than scratched the surface of thoracic surgery but I would like to point this out. You are not getting your great accomplishments over to practitioners throughout the country. I believe you should make a greater effort to get this work into all the journals, not only the JOURNAL OF THORACIC SURGERY, but into the various state meetings and such places where medical men assemble. You should get over to the men the possibilities of chest surgery. Impress upon them the urgency of looking at each patient, especially the adult patient, from the chest point of view, and of taking thoracic roentgenograms of all adult patients.

Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty fifth Annual Meeting of the American Association for Thoracic Surgery will be held April 24, 25, and 26, 1955, in Atlantic City, New Jersey Headquarters will be at the Chalfonte Haddon Hall

Requests for Hotel Reservations

These should be mailed directly to Miss Doris Sears, Convention Manager, Chalfonte-Haddon Hall, Atlantic City, New Jersey Please mention this Association, the type of accommodation desired, date and approximate hour of arrival If accommodations are desired elsewhere in Atlantic City, please communicate directly with the hotel of your choice

Thoracic Surgical Forum

By vote of the membership, the Forum is to be continued for the presentation of short papers on current thoracic research, experimental problems, anatomical studies and modified or new surgical techniques The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers or to suggest their transferral to the regular program Papers at this session will be limited sharply to ten minutes, including the showing of lantern slides or other illustrative material At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper

These papers will be published together in one issue in the JOURNAL OF THORACIC SURGERY Maximum length *3,000* words without illustrations *If illustrated, an appropriate* number of words must be subtracted for each cut used

Abstracts for Papers

Abstracts for the presentation of papers at the 1955 meeting, including papers before the Forum, must be received on or before Dec 15, 1954, otherwise they will not be considered by the Program Committee

Abstracts should be labeled "For Thoracic Surgical Forum," or "For Regular Program"

Five, repeat, five copies of each abstract must be sent to the Secretary of the Association, Dr Paul C Samson, 3959 Happy Valley Road, Lafayette, California They should *not* be sent to the Editor

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec 15, 1954, otherwise, the applications will be deferred for consideration until 1956

Applicants must be sponsored by three Active or Senior members of the Association In addition to the signatures on the application form, the sponsors must forward a *separate* letter concerning the applicant directly to Dr Lyman A Brewer, III, Chairman of the Membership Committee, 2010 Wilshire Blvd, Los Angeles 5, Calif

Completed application forms and the sponsoring letters *independently* sent by the three sponsors must be received by Dr Brewer not later than Dec. 15, 1954, to be considered for action in Atlantic City

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year

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Original Communications

THE CONSERVATIVE AND SURGICAL MANAGEMENT OF BENIGN STRICTURES OF THE ESOPHAGUS

PAUL H HOLINGER, M D, KENNETH C JOHNSTON, M D (BY INVITATION),
WILLIS J POTTS, M.D , CHICAGO, ILL , AND FERNANDO DACUNHA, M D
(BY INVITATION), RIO DE JANEIRO, BRAZIL

BENIGN strictures of the esophagus present a variety of problems which influence the choice of therapy Management is dependent upon the etiology of the stenosis the age of the patient the severity and duration of obstruction and the success or failure of previous therapy Constant re-evaluation of each patient during the course of treatment must be considered and the therapeutic program made flexible enough to allow for minor or major changes according to the response to treatment

Benign strictures of the esophagus are common clinical entities They may be congenital inflammatory chemical traumatic or surgical in origin They vary in degree and extent from small superficial webs to extensive fibrous stenosis or complete atresia they range in duration from recent acute obstruction to years of minimal or moderate disability often of unknown or forgotten etiology

An increasing interest of internists and surgeons in lesions of the esophagus focuses attention on the problems of benign strictures of the esophagus A review of the literature demonstrates the large number of such cases that were treated in the past by otolaryngologists and some gastroenterologists by peroral endoscopic or retrograde techniques They were primarily concerned with the caustic strictures congenital stenoses strictures due to advanced cardiospasm peptic ulcers of the esophagus often associated with congenitally short esophagus or hiatus hernia

In recent years the additional problem of stenoses following repair of esophageal atresia resection of benign esophageal strictures and stenosis following resection of gastric or esophageal carcinoma have created a new group of cases These now require an evaluation not only of therapy per se

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From The Children's Memorial Hospital St Luke's Hospital and the University of Illinois College of Medicine Chicago Ill

Read at the Thirty-fourth Annual Meeting of The American Association for Thoracic Surgery at Montreal Quebec May 3 to 5 1954 but also an analysis to indicate the rapidity with which this problem is increasing in order to emphasize the necessity of avoiding this serious complication, if possible, at the time of surgery.

CONGENITAL STENOSIS OF THE ESOPHAGUS

Congenital stenosis of the esophagus not associated with a congenitally short esophagus may be single or multiple webs or strictures involving segments of the esophagus varying in length from 1 to 10 cm.[1] Congenital webs are not common, and respond immediately and usually permanently to a single dilatation or a short series of dilatations. This procedure may consist of dilatation with an esophagoscope guided through the web over a string or an esophageal bougie, or with graduated mercury-filled rubber bougies that may be rapidly increased in size because of the ease with which the web responds to dilatation. Strictures of whole segments of the esophagus are more common, and from an endoscopic standpoint may be subdivided into two further groups because of their different endoscopic appearance and their variation in response to therapy. In each, the distal esophagus is most frequently involved. Esophagoscopically, the walls of one type appear extremely soft, covered with granulation tissue, and apparently devoid of mucosa. These respond rapidly to dilatation by esophagoscopy or mercury bougies. The second type of congenital segmental esophageal stenosis is a fibrosis stricture, often extremely firm (Fig. 1), and response to dilatation is slower, the stricture is more resistant to dilatation, and the lumen is not maintained for as long a postdilatation period. Many of these were discovered when a foreign body caused complete obstruction and roentgenograms of the esophagus were taken after the foreign body was removed.[2] Analysis of the history of such infants or children showed that they had been considered "feeding problems."

Twenty-three cases of congenital strictures of a segment of the esophagus have been observed in infants and children, 19 cases of congenitally short esophagus complicated by stenosis at the cardia and one simple congenital membranous esophageal web. Of these, 38 have responded to endoscopic or retrograde dilatations. These are first performed esophagoscopically without anesthesia or by retrograde or Plummer bougie dilatation if the strictures are particularly rigid. As soon as possible these procedures are substituted by the mercury bougie dilatation, a procedure which is less uncomfortable for the patient but which is unsuccessful in the early, tighter stricture.

Five of this group of 43 patients with congenital stenoses have been treated surgically—2 by us and 3 elsewhere. Four of the 5 had a surgical excision of the stricture and an intrathoracic gastroesophageal anastomosis. Three operated on elsewhere developed a postoperative stricture at the site of anastomosis which has required endoscopic dilatation identical to that used in the unoperated cases. One described below has had a similar procedure with the anastomosis above the aortic arch with no postoperative dysphagia (Fig. 1, *C* and *D*). The fifth patient had a Ramstedt or Heller type of procedure, but has required occasional endoscopic dilatation.

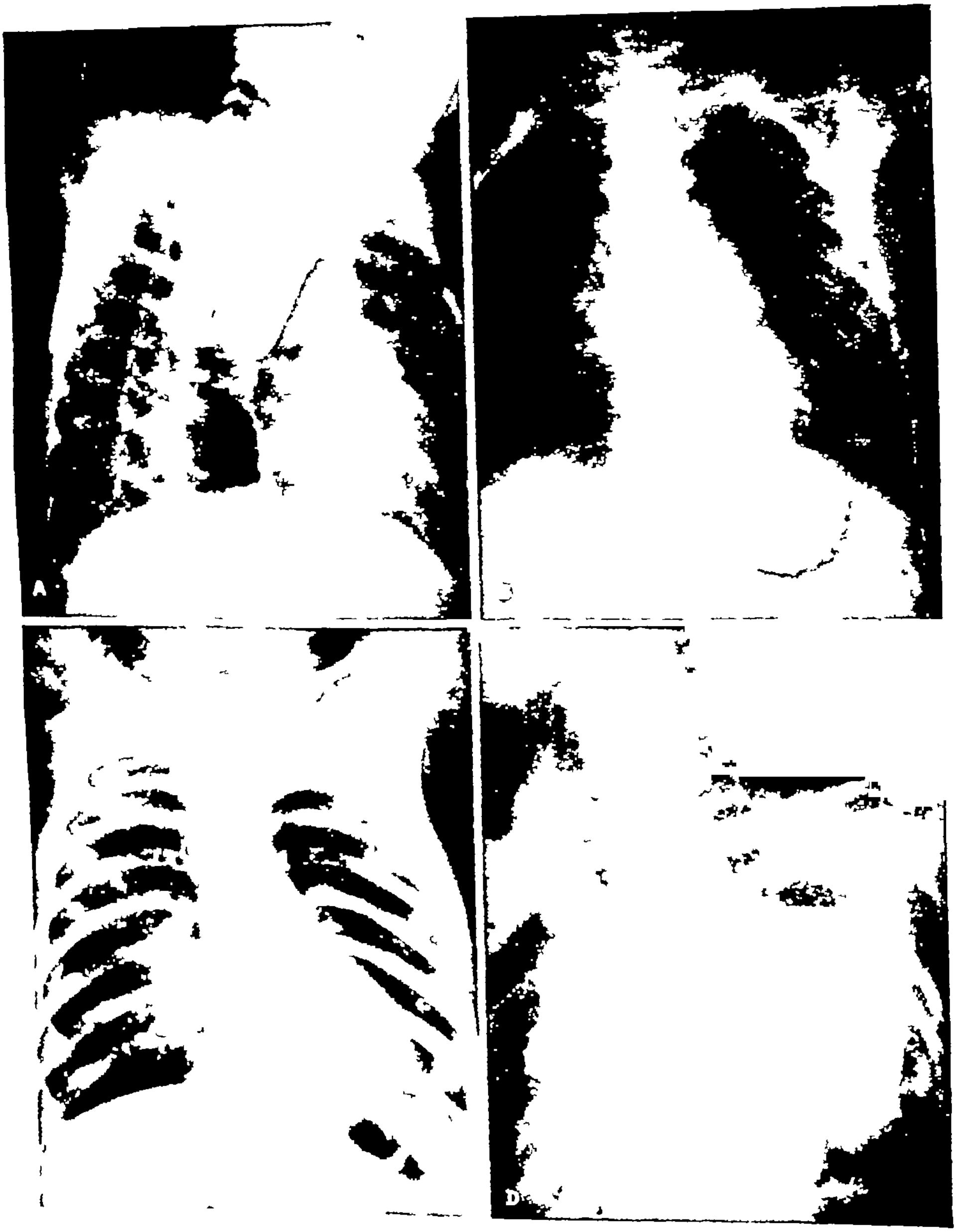

Fig 1.—Two infants with congenital esophageal stenosis A Original roentgenogram of a stricture of the distal half of the esophagus B Same patient showing response to course of endoscopic dilatations The caliber of this lumen has been maintained C Second infant with similar congenital fibrous stricture which did not respond satisfactorily to conservative management D Same patient shown in C following resection of stricture and gastroesophageal anastomosis above the arch of the aorta.

CAUSTIC STRICTURES

We have observed 169 patients with caustic burns of the esophagus. A previous analysis of 96 consecutive cases of this group indicated that acute burns constituted one-third of the patients in this category, while the remaining two-thirds of the patients had chronic stenosis of varying degrees.[3] Twenty-seven of the 65 patients with chronic strictures had complete atresia at the time of their initial hospitalization. Dilatation from above and below and, in 5 cases, perforation of the atresic strictures with the Barretto needle under biplane fluoroscopic visualization[4, 5] resulted in recanalization of all but 2 patients who had had complete atresia. A skin tube esophagus in one of these cases was successful ten years ago. A similar procedure in the second was unsuccessful; this was followed by an anastomosis of the stomach with the cervical eophagus. Stenosis has developed at the point of anastomosis which has required repeated endoscopic dilatation. In 3 of the patients with complete atresia, all children under 3 years of age when first seen, each having had a gastrostomy of more than one year's duration, and in one adult recanalization was successful, but because of the inability to maintain the patency of the esophagus with endoscopic dilatation, various surgical measures were ultimately employed. An esophageal-jejunal anastomosis was performed in two cases as described. The strictured distal esophagus was resected in the other two cases, and an intrathoracic gastroesophageal anastomosis was performed. Return of dysphagia necessitated resumption of endoscopic dilatations in the latter two patients to maintain the patency of the site of anastomosis. There has been one death elsewhere following esophageal resection of the caustic stricture in one patient in this series.

Retrograde, prograde, and endoscopic dilatations have been successful in opening and maintaining the esophageal lumen in the remaining patients with chronic strictures resulting from caustics. The most rapid and successful technique for this group, particularly in the presence of a gastrostomy, is the dilatation with a Plummer bougie over a string held taut in the gastrostomy opening.

In cases of acute, early, caustic burns active dilatation is begun twenty-four to forty-eight hours after ingestion of the caustic, using the soft-rubber smooth-tipped, catheter-like bougies filled with mercury. Graduated sizes from 16 Fr. to 30 Fr. for children or up to 48 Fr. for adults are well lubricated before being inserted in the mouth. They advance to the stomach by their own weight.[6] Two or three bougies are used daily, gradually increasing the size during the first two weeks. Dilatations are then spaced twice a week for a month, then once a week for another month. Subsequent dilatations are continued at monthly intervals for a year and then the period between dilatations is increased. *It is of utmost importance that the patient continue with this regime.* The tragedy in most cases of esophageal strictures is that the family and often the physician, are not aware that the return of normal or almost normal swallowing occurs after the acute edema associated with the original burn subsides. Treatment must be continued during this period of relative lack of symptoms if stricture formation is to be avoided. In acute cases there has been no stricture formation in those patients seen who have maintained this course of therapy. Strictures have formed when treatment has been discontinued for one reason or another by the patient or the family or when treatment has been delayed and the patient is seen late.

There have been seven deaths in this group of caustic strictures, one, an infant who had been given lactic acid by accident was first seen approximately six weeks after the ingestion of the acid, and the esophagus was almost completely closed. This infant died after perforation of the esophagus which occurred during dilatation before the present chemotherapy and antibiotics were available. The second death occurred in an 8-year-old girl and was due to aspiration pneumonia which was the result of a chronic tracheoesophageal fistula. The third fatality was a man who had swallowed a large quantity of "boiler fluid," a combination of sulfuric acid and hydrochloric acid. He had multiple esophageal strictures, marked destruction and extensive scarring of the stomach and duodenum, and eventually required a jejunostomy for feeding purposes after a gastroenterostomy proved to be unsuccessful. Death was due to gradual inanition, and had no relation to esophageal instrumentation. The fourth patient died during the acute stage of an acid burn thirteen days after ingestion of nitric acid, four days after having coughed up a cast of the entire esophagus. The fifth death followed esophageal resection of the stricture. The sixth death was due to an extensive malignancy of the upper esophagus in an adult who had a lye stricture since childhood. The seventh was that of a 2-year-old boy with an extensive burn that caused an atresia of the pharynx, larynx and esophagus who was found dead in bed when his tracheotomy tube was apparently coughed out.

During the past five years five perforations of the esophagus have occurred during esophagoscopic dilatation of a caustic stricture, all recovered—three with conservative management alone, one requiring mediastinotomy and the fifth a thoracotomy. No perforations have occurred during mercury bougie dilatation.

In recent years the use of cortisone and ACTH have been strongly advocated by some for the management of acute caustic burns of the esophagus. The relief of pain, the general improvement of swallowing function and the apparent reduction in scar tissue formation have indicated that this therapy is an important adjunct to the management of these patients. Therapy suggested by Barretto[8] Palmer[9] Grez[10] and others is as follows. Beginning with the first day ACTH 5 to 7.5 mg in children and 10 to 15 mg in adults is administered intravenously daily with 5 per cent glucose. Vitamins B and C, penicillin and streptomycin are administered in adequate dosage. After the tenth to fifteenth day cortisone 75 to 150 mg three times a day is administered orally for one month. Daily mercury bouginage is begun on the fifth to tenth day. However while the immediate effects of this early therapy are dramatic it is becoming apparent that esophageal perforations, severe gastric hemorrhage, gastric perforation and a rise in the incidence of gastric and particularly pyloric stenosis follow this regime.[11]

HIATAL HERNIA

The stenoses associated with hiatal hernia, peptic ulcer, feeding tube ulceration, and cardiospasm constitute a group of benign inflammatory strictures at and immediately above the cardia in adults. The association of stricture formation in hiatus hernia in our series is undoubtedly higher than in an unselected group since patients were referred because of obstructive symptoms. Medical management played a significant role in the treatment of all patients.[12] Those cases uncomplicated by stricture formation treated by surgical replacement of the supradiaphragmatic stomach and diaphragmatic repair responded satisfactorily. However, the difficult problems of management in this group are those patients in whom varying degrees of stricture formation is present at the cardia. Medical ulcer management, surgical repair of the hiatal defect and endoscopic dilatation require considerable cooperation on the part of the patient. This has been reasonably effective in most cases. In six patients, all adults, resection of the stricture and esophagogastric anastomosis has given only temporary relief at best. In each, the stenosis has re-formed in a period of from three months to two years, necessitating resumption of the endoscopic dilatations.

CARDIOSPASM

It has been demonstrated that the great majority of patients with cardiospasm respond favorably to an occasional dilatation with mercury filled bougies, or pneumatic or hydrostatic bag dilatation. In 452 of 601 traced cases reported by Olsen,[13] 60.1 per cent responded to an initial course of hydrostatic dilatation and an estimated 75 per cent to a second course. Recurrence of symptoms varied from a few months to several years. In this series of benign strictures there were 236 cases of cardiospasm, the majority of which responded to dilatation. The procedure was first done esophagoscopically, if severe ulceration was noted, the patient was placed on ulcer management until re-examination demonstrated clearing of the ulcer. The cardia was then actively dilated with a pneumatic bag under fluoroscopic control, the passage of the bag through the cardia often facilitated by guidance over a previously swallowed thread. The fluoroscopic control of the placement of the bag is significant, as indicated by the frequency with which lack of such control fails to give adequate relief and the observation of the manner in which the bag often curls on itself as attempts are made to direct it through the cardia. In patients with extreme enlargement of the esophagus or in those whose response to dilatation is unsatisfactory, surgical consultation is recommended. The total number of patients operated on is not known. However, of nine patients who were operated on by various procedures, there were two postoperative fatalities elsewhere. Seven had a recurrence of obstructive symptoms severe enough to necessitate resumption of dilatations in much the same manner as was done prior to operation and therefore, are discussed as postsurgical benign esophageal strictures. It is significant that the surgical procedures almost invariably give the same relief from obstructive symptoms the patient experiences following his initial endoscopic or pneumatic bag dilatation. The response may be most gratifying to the patient for the first year or two, but, as with dilatation procedures, recurrence of symptoms gradually becomes manifest after that interval of time. Of the seven postoperative recurrences five had gastroesophageal anastomoses with resection of the strictured segment and two had Heller operations. Two of the seven had not been seen preoperatively; one who had a resection of the stricture and a gastroesophageal anastomosis elsewhere had been dilated unsuccessfully preoperatively. The second who had a Heller operation had a very minimal cardiospasm, judging by the preoperative symptoms and films, and had no preoperative esophagoscopy or dilatation of any type. The postoperative stricture undoubtedly was increased in severity by mediastinitis and empyema, the result of infection of the operative site.

This is not to be misconstrued as a condemnation of surgery for uncontrollable cases of cardiospasm. In a discussion of benign strictures of the esophagus these postoperative strictures play an increasing role both statistically and with regard to their resistance to treatment. Analysis of these failures to both peroral dilatation and external surgery (excision or muscle splitting) suggests that strictures re-form because of peptic esophagitis caused by reflux regurgitation of gastric secretions. Surgical procedures to counteract this problem have been suggested[14] and it would appear that recurrence of stenosis in these seven cases may be due to failure to include measures which will reduce the acid secretion.

Six infants with cardiospasm have been reported previously.[1] These have responded to endoscopic dilatation, although one necessitated gastrostomy and retrograde dilatation because of the severity of the stricture.

SURGICAL TREATMENT

There is agreement between the endoscopic and surgical divisions that dilatation of esophageal strictures should be continued until it becomes apparent that a functional esophagus cannot be obtained by conservative measures. We believe that even a fairly good esophagus is generally preferable to food passages which are made by various types of surgical procedures.

During the past four years at Children's Memorial Hospital, we have performed various operations on eight patients for congenital and post-lye strictures and for congenital atresia of the esophagus not associated with tracheoesophageal fistula. The more interesting of these cases will be briefly abstracted.

Case 1.—L. B., born Dec. 7, 1943, swallowed lye when 1 year old, had a gastrostomy elsewhere and was admitted to the Children's Memorial Hospital Sept. 4, 1946, in very poor condition with a complete esophageal atresia. The lumen was re-established endoscopically with biplane fluoroscopic guidance. During the next four years the child had many dilations of the esophagus with the Plummer dilator and later with the retrograde bougies. It finally became apparent that although the esophagus could be opened, it would not remain open without frequent dilatations.

On Nov 17, 1950, an esophagojejunostomy was performed according to the method described by Robertson[15] (Fig 2) A loop of jejunum was isolated and the peritoneum carefully separated from both sides of its mesentery After cutting three primary radicles it was apparent that the jejunum would be long enough to reach to the esophagus in the neck The jejunum was cut about ten inches distal to the ligament of Treitz A transverse incision was now made in the neck above the manubrium and the left clavicle where the esophagus was dissected from its bed with considerable difficulty because of dense fibrous adhesions By means of blunt dissection behind the manubrium above and behind the sternum below, mostly by finger, the retrosternal space was opened The proximal end of the jejunum was drawn through this tunnel behind the sternum and brought a few centimeters above the clavicle where it was anastomosed to the upper end of the esophagus by two layers of fine interrupted silk sutures Even at this high point in the neck, the lumen of the esophagus was so narrow that a longitudinal split in its lower end was necessary to allow an adequate anastomotic channel The distal end of the esophagus left in the chest was closed with a few silk sutures The cut end of the jejunum in the abdomen was anastomosed to the side of the jejunum in a Roux Y type of anastomosis The abdomen was closed without drainage, a small Penrose drain was placed in the outer angle of the skin wound in the neck, and a temporary tracheotomy was performed The postoperative course was uneventful except for slight infection of the neck wound which did not delay recovery Two weeks after surgery, fluoroscopic examination and roentgenograms (Fig 3) showed the retrosternal jejunal esophagus functioning satisfactorily It has continued to function satisfactorily

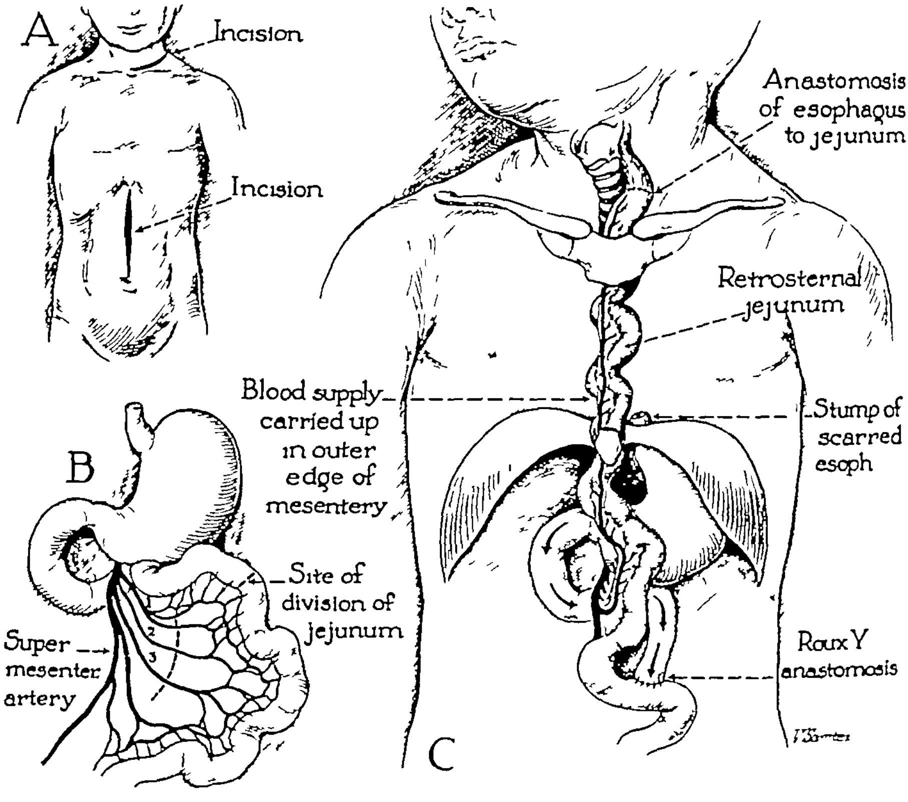
A
Incision
Incision
B
Blood supply carried up in outer edge of mesentery
Site of division of jejunum
Super mesenter artery
2
3
Anastomosis of esophagus to jejunum
Retrosternal jejunum
Stump of scarred esoph
Roux Y anastomosis
C

Fig 2—Esophagojejunostomy and Roux-Y anastomosis performed for intractable lye stricture

Case 2.—M. H., born Nov. 13, 1945, swallowed lye at the age of 2½ years and was admitted to Children's Memorial Hospital, April 9, 1949. He had had a gastrostomy elsewhere. Dilatations of the esophagus, constricted from the mid cervical region to the cardia, were continued persistently until 1952. While the esophagus could be opened, often it closed down within a week to permit only the swallowing of liquids. At operation April 25, 1952, when the child was 6½ years old, exactly the same operation was performed as in Case 1. The patient had no trouble swallowing, ate everything with the speed of the average hungry boy and had no distress. Although his gastrostomy closed spontaneously a couple of months after esophagojejunostomy, it broke open one year later and allowed study of the by passed stomach. Analysis of the acid content of the stomach every two hours for eighteen hours showed free and combined acidity each about 10 degrees higher than normal. Gastroscopic and fluoroscopic examination of the stomach showed no variation from normal in the gastric mucosa and no filling defect.

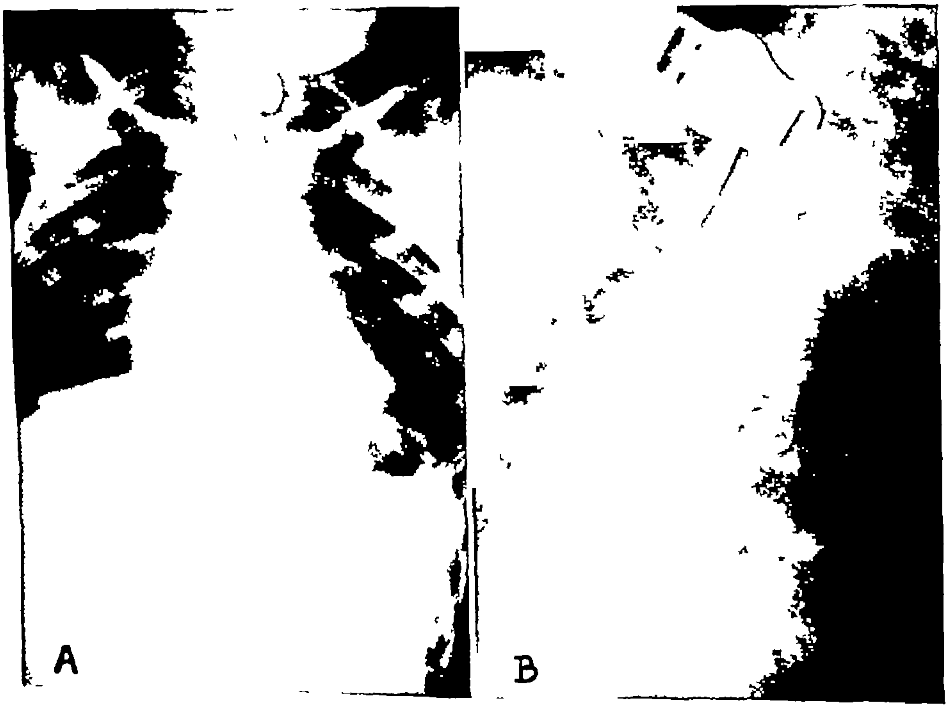

Fig. 3.—Pre and postoperative esophagrams of lye strictures (Case 1) operated according to the procedure illustrated in Fig. 2. A, Preoperative film showing fibrous stricture of distal one third of esophagus and high firm fibrous web. B, Esophagojejunostomy above the clavicle. The tracheostomy was temporary.

Case 3.—K. K., born Aug. 26, 1951, was admitted to the hospital on August 30, with congenital atresia of the esophagus without tracheoesophageal fistula. A gastrostomy was promptly done. A small catheter passed through the gastrostomy tube was directed into the lower end of the esophagus which was demonstrated to be about a centimeter long. Lipiodol studies of the upper end of the esophagus showed that it ended at the level of the second thoracic vertebra. Since it obviously was impossible—at least had been so for us in previous similar cases—to bring the ends of such widely separated segments of the esophagus together, the upper end of the esophagus was exteriorized above the left clavicle.

When the patient was three months old an esophagojejunostomy was performed according to the technique described under Case 1. Adequate length for the jejunum to reach to the cervical esophagus was obtainable by section of only two primary arcade vessels. The jejunum placed behind the sternum was easily brought to the cervical esophagus but even though only two arterial radicles had been cut, the jejunum was a bit dusky after anastomosis when the upper end of the esophagus had been completed. Following operation much swelling and considerable infection occurred about the neck wound, some sloughed tissue was extruded. Saliva appeared in considerable quantities and a swallow of Lipiodol showed nothing going through the jejunum.

On Jan. 4, 1952, the neck was explored and the distal end of the jejunum could not be found above the manubrium. We assumed that the end had sloughed away. The upper end of the esophagus was exteriorized and the patient sent home. About eleven months later the child returned to the hospital and on Nov. 13, 1952, the upper abdomen was opened and the proximal part of the limb of the jejunum previously placed behind the sternum was identified. Into it 10 c.c. of Lipiodol was injected, roentgenograms showed that the jejunum was still intact to approximately the upper edge of the manubrium. The sternum was then split longitudinally and the jejunal limb freed from surrounding tissues. Only at the upper end were the adhesions dense. Fortunately, after freeing the jejunum without impairing its blood supply, its upper end could be placed near the previously exteriorized esophagus. Because healing had been by primary union, it seemed safe, on Nov. 23, 1953, to explore the neck and complete the anastomosis between jejunum and esophagus. Although there was no tension on the suture line, the anastomosis broke down and saliva was discharged from the neck wound. However, a swallow of Lipiodol showed tiny quantities of the contrast medium going through the jejunum.

The child was sent home again for six months. During all of this time the gastrostomy tube was, of course, in place for feeding. On return to the hospital, unsuccessful attempts were made to get a string through the anastomosis as a guide to dilatation. The child could swallow liquids which ballooned out the esophagus and slowly went through the stricture. Attempts to dilate with an esophagoscope also met with failure. On April 12, 1954, the neck was again explored, after separating many adhesions the intact, but markedly constricted anastomosis, was exposed. The stricture was cut longitudinally and sewed transversely over a No. 20 Fr. catheter. Postoperative healing has been by primary union, but the child cannot swallow fluids without difficulty. Roentgenogram studies show considerable stricture.

We have performed esophagojejunostomies as described on three patients, two had no postoperative complications of any kind and no digestive difficulties or complaints for four and two years, respectively. Failure of anastomosis in the third child has necessitated repeated operations, but an eventually satisfactory result seems assured.

Our experience is too limited to know whether an intrathoracic gastroesophagostomy is a better operation. Thus far by passing the stomach in two patients, each about 7 years of age, had led to no trouble. Perhaps it would be wise to attach the jejunum to the stomach now. This procedure would not be difficult since the retrosternal limb of the jejunum crosses the anterior surface of the stomach.

For a fourth patient with congenital atresia of the esophagus without tracheoesophageal fistula previously reported,[1f] the stomach was transplanted beneath the skin but in front of the sternum. It was very unsightly in this position and eventually was successfully moved into the chest through an incision which involved cutting all the ribs and the clavicle on the left side

Transplantation of even the jejunum beneath the skin of the anterior chest wall for an esophagojejunostomy at the neck seems less desirable to us for cosmetic reasons than retrosternal placement.

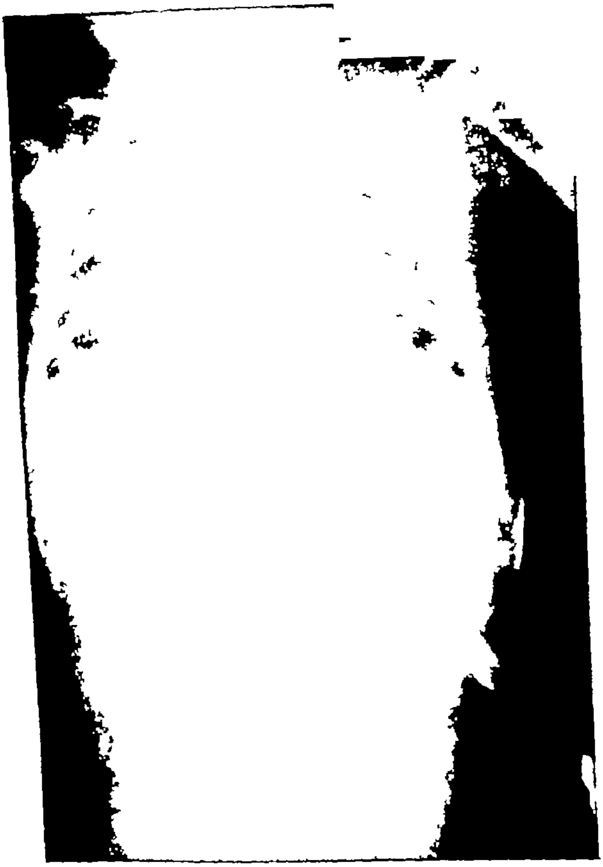

Fig 4.—Case 4. Congenital fibrous stricture of distal esophagus necessitating gastrostomy because of rigidity of the stenosis.

CASE 4.—J. R., born March 24, 1947, was admitted to Children's Memorial Hospital, June 16, 1947, with a history of vomiting uncurdled milk in increasing quantities for nine weeks. Roentgenographic studies showed a stricture of the esophagus just above the cardiac orifice (Fig. 4). It was impossible upon repeated attempts with an esophagoscope to find an opening through the constricted esophagus. A gastrostomy was done and the child brought to normal food intake. Later, under biplane fluoroscopic observation, it was impossible to find an opening through the stricture with simultaneous approach with one esophagoscope introduced through the esophagus from above and another from below through the gastrostomy.

At operation on Sept. 12, 1947, the lower end of the esophagus was exposed through a left posterolateral chest wall incision. Except for some palpable thickening the esophagus showed no abnormality. A catheter was introduced from above to outline the beginning of the constriction. Not recognizing the pathology as anything previously seen or read about, it seemed appropriate to cut into the stricture. A longitudinal incision through the rather firm mass revealed dense fibrous tissue which resembled in appearance, feel, and size the tumor of congenital pyloric stenosis (Fig. 5). The mucosa was then cut longitudinally, and immediately after it had been done it was regretted. The entire mass so much resembled pyloric stenosis that it might well have been treated as such, that is, by cutting the constricting tumor and leaving the mucosa intact. The catheter previously placed in the esophagus was directed into the stomach. Since the mucosa had been split, it was freed somewhat from the dense fibrous tissue on each side and closed transversely over the No. 16 catheter. The rather tough fibrous tissue with the loose adventitia lying above it could be closed transversely, after a fashion, over the sutured mucosal layer. The catheter was removed from the esophagus and the chest was drained with a stiff tube, the open end of which was sewed in place near, but not touching the repaired site. Discharge from the drainage tube of regurgitated stomach contents and saliva began a couple of days after surgery but ceased spontaneously; when the child was discharged from the hospital one month after operation he was able to swallow liquids and semisolid foods. The gastrostomy was allowed to close spontaneously. Occasional endoscopic dilations of the esophagus have been necessary; the patient returns occasionally for these examinations to be sure the stricture is not recurring.

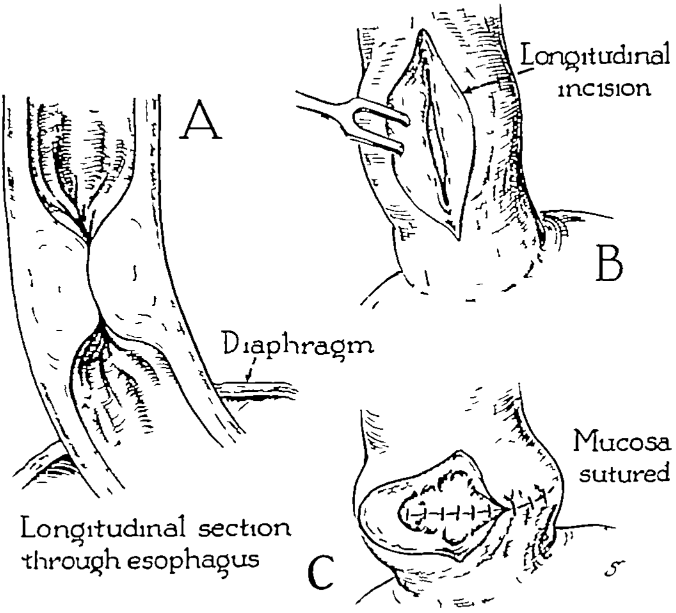

Fig. 5.—Case 4. Diagram of longitudinal incision and transverse closure of congenital fibrous stricture of distal esophagus of 3 month old infant.

This unusual case of congenital stricture was entirely new to us. A similar case has not been seen reported but undoubtedly has occurred. We believe that another such case might be treated surgically as congenital pyloric stenosis, i.e., cutting the fibrous constriction and leaving the mucous membrane intact.

The two other patients with strictures which involved only the intrathoracic portion of the esophagus were treated surgically by gastroesophagostomy. One anastomosis for a low stricture was performed below the arch of the aorta the other for a congenital stricture had to be done above the arch (Fig 1) Although both anastomoses were done exactly the same way the one performed below the arch has been followed by stricture which has required many postoperative dilations the other has remained open without any difficulties or narrowing

POSTSURGICAL STRICTURES

An aspect of benign strictures of the esophagus which is becoming of increasing concern is the postsurgical stricture It has been mentioned under the various categories discussed above and is now summarized as a separate entity not only because of its actual frequency but because of the rapidity with which this group has increased Cases may be divided into four groups (1) stenosis following the repair of congenital esophageal atresia with or without tracheoesophageal fistula (2) stenosis at the point of anastomosis following the resection of a benign stenosis (congenital stenosis lye stricture chronic inflammatory stenosis associated with peptic ulcer of the esophagus cardiospasm etc) (3) stenosis following surgery of the esophagus for nonstenosing lesions (diverticulum thyroidectomy etc) and (4) stenosis following resection for carcinoma

Stenosis Following Repair of Congenital Esophageal Atresia—Postsurgical strictures commonly develop following repair of congenital esophageal atresia with tracheoesophageal fistula The configuration of the proximal portion of the distal segment and the inability to bring the ends of the segments together with sufficient tissue for adequate repair are but two of the reasons that these strictures may follow anastomosis From the standpoint of the esophagoscopist who must be responsible for maintaining the patency of the lumen at a later date therapy should begin at the time of anastomosis if there is any question of a potential narrowing in this area A thread passed through the stricture is of inestimable value and maintains the patency of the lumen Without it subsequent dilatation is hazardous and often impossible Therefore at the earliest indication of dysphagia the infant should be given a fine thread to swallow this followed by a No 14 or No 12 woven silk thread By passing a small catheter through the nose the thread can be tied to it returned through the nostril and anchored in a more satisfactory manner If a gastrostomy is necessary for feeding purposes, the thread can be recovered in the gastrostomy opening with an aspirator and a continuous thread established by tying the two ends together Subsequent dilatations over this thread are the most satisfactory form of therapy using either retrograde or olive tipped prograde bougies

There are twenty six infants and children in this group Approximately half of these were operated on elsewhere and referred later for postoperative dilatation as obstruction progressed (Fig 6) The remaining half represents approximately one fourth of the total group of *living* tracheoesophageal fistula patients operated on at the Children s Memorial Hospital The early frequent esophagoscopic retrograde or Plummer bougie dilatations over a string are gradually decreased in frequency with the interval between treatments being dependent upon the symptomatology These dilatation techniques are dispensed with as soon as possible and the easier mercury bougie dilatations can be substituted

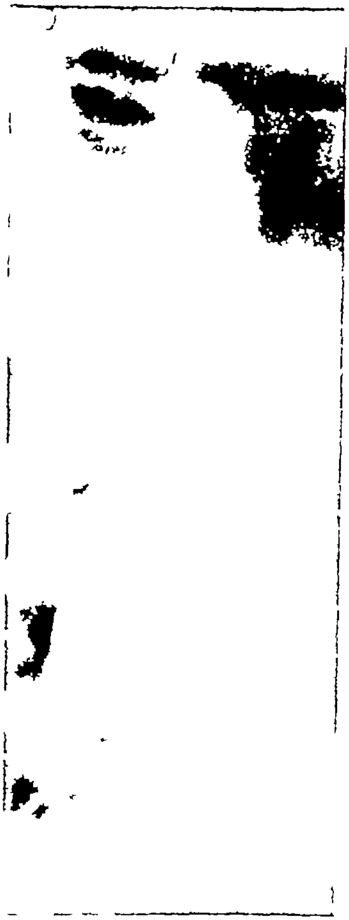

Fig 6 —Stricture at site of anastomosis of the two esophageal segments of a congenital esophageal atresia and tracheoesophageal fistula.

It is of interest to note that two of the infants with these postsurgical strictures and two additional tracheoesophageal fistula infants who have not developed esophageal stenosis have serious tracheal stenoses at the site from which the lower esophageal segment was removed from the trachea and the dehiscence closed

Recurrent Stenosis Following Resection of a Benign Stricture.—In this group may be listed three cases of recurrent stenosis following resection of lye strictures five cases of recurrence of stenosis following resection of congenital strictures eight cases of recurrence following resection of stenosis associated with hiatal hernia and peptic ulcer of the esophagus and seven cases of recurrence following various surgical procedures for cardiospasm

Stenosis Following Surgery for Nonstenosing Lesions of the Esophagus.—In addition to the surgical stenoses occurring for the most part in the distal esophagus are a group of severe benign stenoses of the cervical esophagus that have followed operative procedures for benign lesions in the neck. Two of these have followed thyroidectomy; one was severe enough to necessitate a gastrostomy before the lumen could be adequately dilated to permit a satisfactory intake. Seven have followed the removal of a pulsion (Zenker's) diverticulum of the hypopharynx. These are apparently the result of too zealous an effort at adequate water-tight closure of the esophagus after the sac is removed or the attempt to avoid recurrence of the diverticulum by increasing the support along the suture line with additional suture layers. When several layers of closure are made with full-thickness layers the lumen must obviously be reduced. In one patient who had a pulsion diverticulectomy a complete atresia was present, the patient being unable to swallow his saliva. This stricture was eventually opened by retrograde dilatation through a gastrostomy. The remainder have been dilated esophagoscopically or with mercury bougies to restore normal swallowing function.

Stenosis Following Resection of Carcinoma of the Esophagus.—Repair of the esophagus following resection of a carcinoma presents surgical problems which are the result of many variable factors. Should a stricture follow such a repair, it is of minor importance in relation to the original carcinoma which has been removed. From an endoscopic standpoint the tortuous dense fibrous postoperative scar is nevertheless difficult and dangerous to dilate because of its rigidity and tortuous course and because one must always bear in mind the possibility that the return of dysphagia may be evidence of a return of carcinoma (Fig. 7). Twenty-eight patients with resections of the lower or mid-thoracic esophagus have required repeated dilatations of the anastomosis during the past three years. Since the majority showed recurrence of the carcinoma at the anastomosis site, re-resection or the insertion of polythene tubes endoscopically has been done in addition to the repeated dilatations.

As in the postsurgical strictures following resection of benign lesions, a separate group is made up of those strictures that followed resection of malignant lesions involving the cervical esophagus. Twelve of these are postlaryngectomy stenoses in which the pharyngeal closure has been followed by stenosis because of partial pharyngeal resection. Much more complicated are those that follow the increasingly radical pharyngeal and laryngeal resections that are performed for more extensive malignant lesions of these areas. Stenoses frequently occur at both the upper and the lower sites of anastomosis of skin tubes used in these patients. Often no type of dilatation is possible because of the tortuous subcutaneous path which has been constructed and because of the fibrous rigidity of the stricture itself. Occasionally, if the patient can swallow a thread, dilatation of the tortuous path can be accomplished to improve swallowing function. The relief such patients experience in being able to swallow their saliva, even though nutrition has been maintained by gastrostomy feeding, is sufficient to justify hours of effort However, this problem is so materially decreased in severity if a string is inserted at the time of surgery that it would seem justified to consider this as a routine part of these operations

Fig 7—Postsurgical stricture at site of a gastroesophageal anastomosis following resection of a carcinoma of the distal esophagus

SUMMARY AND CONCLUSIONS

The management of benign strictures of the esophagus varies according to the etiology, degree, and duration of the stricture, the age of the patient, and the success or failure of previous therapy There is agreement between the endoscopic and surgical divisions at the Children's Memorial Hospital that dilatation of esophageal strictures should be continued until it becomes apparent that a functional esophagus cannot be obtained by conservative measures

Dilatations of benign strictures of the esophagus are performed in several ways, depending on the location size and rigidity of the stricture They may be done by esophagoscopy either using bougies through the scope or by the scope itself, by Plummer bougies passed over a previously swallowed thread, by retrograde Tucker bougies in some gastrostomized patients by graduated mercury-filled bougies, or by pneumatic bougies correctly placed under fluoroscopic guidance No anesthesia is used in infants or children local anesthesia in adults In our experience the most rapid and the safest method of dilating tight, fibrous strictures has been a gastrostomy and peroral Plummer bouginage over a string held taut at the gastrostomy opening The most satisfactory method of dilating an early less fibrous stricture has been by graduated mercury-filled rubber bougies

In a review of our series of benign strictures of the esophagus there are 43 cases of congenital strictures 1 simple web, 23 strictures of segments of the esophagus and 19 cases of congenitally short esophagus with a stricture at the cardia Thirty-eight responded to dilatation 4 were operated on by excision of the stenosis and intrathoracic gastroesophageal anastomosis, and 1 was operated on by a musclesplitting procedure Postoperatively 3 of the 4 having had a gastroesophageal anastomosis elsewhere required resumption of endoscopic dilatations identical to those preceding operation

There are 169 patients with caustic burns and strictures of the esophagus Approximately one half were chronic strictures, of which 27 had complete atresia that necessitated biplane fluoroscopic guidance to recannulate the lumen Of those who did not respond to dilatation, skin tubes were constructed (more than ten years ago) in 2 patients, 1 was successful 1 was not In 2 retrosternal esophagojejunal anastomoses were performed with complete relief of dysphagia, in 3 intrathoracic gastroesophageal anastomoses were performed Endoscopic dilatation has been necessary in these 3 because of severe strictures at the site of anastomosis In the management of acute burns the use of antibiotics and early bouginage by mercury-filled bougies is stressed ACTH and cortisone produce a dramatic early relief of pain and dysphagia but reports of severe gastric and esophageal hemorrhage, perforations and late gastric and pyloric strictures are appearing in the literature to place a note of caution on this regime

In all of 6 adults operated on for strictures of the gastroesophageal junction associated with hiatal hernia recurrence of the stricture at the point of the anastomosis has necessitated resumption of the peroral dilatations In 236 cases of cardiospasm 75 per cent have responded to an occasional pneumatic bag or mercury bougie dilatation Of 7 patients operated upon in whom resumption of dilatation was required after surgery, 5 had had resection of the cardia and gastroesophageal anastomosis and 2 had had Heller operations none had additional procedures designed to reduce the acid secretion of the stomach

There were 96 patients who had benign postsurgical strictures of the esophagus Twenty six were infants or children who had stenoses following repair of congenital esophageal atresia and tracheoesophageal fistula Eighteen were patients who had developed stenoses at the site of anastomosis following resection of a benign stricture 3 following resection of a lye stricture, 2 following resection of a peptic ulcer with stenosis 6 following resection of a stricture associated with hiatal hernia and 7 following surgery for cardiospasm Nine patients had had esophageal stenosis following surgery for *non-*

stenosing esophageal lesions, 2 following thyroidectomy, and 7 following resection of a pulsion (Zenker's) diverticulum. In one of each of the latter two categories complete atresia necessitated gastrostomy and retrograde recanalization. In 28 patients seen in the last three years, benign stenosis has developed in the anastomosis following resection of carcinoma of the esophagus or stomach. In 15, stenosis of the cervical esophagus has necessitated dilatation following laryngectomy and partial pharyngectomy or following the skin tube procedures designed to replace the esophagus in resection of carcinoma of the cervical esophagus.

Seven patients operated on for benign strictures of the esophagus at the Children's Memorial Hospital are presented. In two patients gastroesophageal anastomoses were performed one above the arch of the aorta for a congenital stricture who now has normal swallowing function and one below the arch for a lye stricture with a recurrence of stenosis. One infant with a congenital fibrous stenosis immediately above the cardia had almost completely normal swallowing function following longitudinal incision and transverse suturing of the fibrous segment. Three children have had cervical gastrojejunal anastomoses two for intractable extensive lye strictures with complete restoration of normal swallowing function and one infant for congenital esophageal atresia. Infection at the anastomosis site has resulted in stenosis in this region which will require further dilatation procedures or surgery. The seventh patient reported previously has normal swallowing function following cervical gastroesophageal anastomosis for congenital esophageal atresia.

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DISCUSSION

DR H. BRODIE STEPHENS, San Francisco, Calif —We have found that the simple measure of raising the head of the crib or bed two feet has been an extremely effective treatment in congenitally short esophagus In the case of the young infant, we have the parents make a harness for the child in order to keep him properly arranged in the crib during the sleeping and resting hours In the case of the adult, he or she is instructed to purchase a hospital bed so that the head of the bed is always elevated This simple expedient of raising the esophagus above the level of the stomach has been an extremely effective method of keeping the stomach contents out of the esophagus When the cardioesophageal junction is too high above the diaphragm by operation, then constantly maintaining the esophagus above the stomach by positioning will often result in the disappearance of the esophagitis that is so commonly present In a few instances of rather severe bleeding in infants due to the lesion we have been able to eradicate symptoms by the procedure described In addition, we believe that we have prevented the development of stricture by insisting that the patient be always in the upright position during the resting hours

DR L D MACLEAN, Minneapolis, Minn —We have been impressed with the extreme sensitivity of the esophageal mucosa to both acid and alkaline secretions, and particularly the therapy of at least one sequela—stricture—by means of subtotal gastric resection While it has been impossible for us to produce this in the experimental animal to date we thought our experience with a small group of cases might be of interest at this time

A total of 12 cases with associated gastric duodenal, or jejunal ulcers, and at times also paraesophageal hiatus hernia, have undergone subtotal gastric resections They have been followed for periods of six months to fifteen years

The difficulty of the first patient operated upon was preceded by an obstructive duodenal ulcer as was indicated by the gastrointestinal series Dilatations were carried out over a four year period following development of dysphagia He did not respond to this therapy and was operated on in September, 1939 by Dr Wangensteen It was not anticipated that this operation would in any way relieve the dysphagia but it did Dilatation had been performed approximately 100 times prior to surgery this was required only twice in the immediate convalescent period The patient has not suffered with dysphagia and is working at the present time

The difficulty of the sixth patient of this series of 12 was also preceded by duodenal ulcer and his dysphagia became markedly worse following perforation of the ulcer Over a period of two months it became impossible for him even to swallow his saliva, and a gastrostomy was done elsewhere Dilatations were begun using first a No 5 Fr ureteral catheter and working up to a No 27 Fr at which time an esophagram was taken He underwent a subtotal gastric resection six years ago

Of the 12 patients all have had symptomatic improvement Eleven of the 12 have evidence anatomically as demonstrated by the esophagram and the ease of passing dilators of enlargement of the esophageal lumen

DR E B BENEDICT Boston Mass —Dr Gillespie and I have recently reported [illegible] cases[1] of peptic esophagitis with stenosis of the esophagus We believe that by having the patient swallow a thread as a guide, and using that for bouginage, we can usually avoid gastrostomy, and most patients do not like a gastrostomy About 80 per cent of our cases had a hiatus hernia and 40 per cent had an esophageal ulcer or a duodenal ulcer, or both In the few cases that require resection, we feel that if the resection is done well above the area of esophagitis the patient will not develop postoperative stenosis In the few cases that did have postoperative stenosis, dilatation, using the thread as a guide was satisfactory, and gastrostomy was not necessary

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[1] Benedict, E B and Gillespie, J [illegible] Peptic Stenosis of the Esophagus Surg Gynec. [illegible]

DR WILLIAM F RIENHOFF, Jr, Baltimore, Md—I should like to call to the attention of the American Association of Thoracic Surgery a patient upon whom I *operated in 1943* * *I believe the jejunum was placed retrosternally in this operation for the* first time This patient of Dr Samuel Crowe, Professor of Otolaryngology, had a lye stricture He had a gastrostomy for about twenty years In order to reconstruct an esophagus, I placed his jejunum behind the sternum, but there was no connection between the stomach and the jejunum Dr Potts raised the question of what would happen eventually when the stomach received no food For the last eight years this patient has had severe hemorrhages from obvious gastric or duodenal ulcers Because he is not very cooperative, he will not come in for an operation to join the jejunum to the stomach I want to point out, therefore, that if you do an esophagojejunostomy and leave the stomach as an empty sac exposed to its own digestive juices without any food or water or anything going *through* it, you are likely to have peptic ulceration

DR MARK M RAVITCH, New York, N Y—In regard to Dr Pott's question, I want to point out that in by passing the stomach we may bring on subsequent diarrhea and malnutrition That has happened to us, and we have had to reinsert the lower end of the anterior esophagoplastic jejunum into the stomach On the other hand, there are very large series of cases in which this has not been necessary, in which growth and nutrition have been compatible with the establishment of a jejunal esophagus, extrathoracic or intrathoracic, by passing the stomach Yet we have had two experiences in young adults with jejunal esophagoplasties for lye strictures who developed anastomotic ulcers because *the lower end of the jejunum* was inserted into the stomach Neither of those people, I believe, bled as much as Dr Rienhoff's famous Willy Turner, whom a number of us in this room remember They do pose problems, however, and I wonder if that type of anastomosis should not be accompanied by vagotomy and pyloroplasty

DR JOHN L POOL, New York, N Y—I, too, should like to discuss the point raised by Dr Potts For replacement of the esophagus after resection of an esophageal cancer, the Ross Robertson type of procedure is available It has the distinct advantage that the replacement procedure is a stage separate from the esophageal resection and carries a lessened mortality than the one stage esophageal resection with immediate esophagogastrostomy Furthermore, one can do a more complete esophagectomy The esophagojejunostomy is in the neck and the patient is left with a good two feet of jejunum proximal to the Roux Y anastomosis

Although this anatomic setup is very satisfactory, there is one physiologic complication—namely, the *"dump syndrome"* *One such patient whose stomach* was still intact and who had a gastrostomy as well as the esophagojejunostomy was studied on the Metabolism Service at Memorial Hospital by Dr Kathleen Roberts and Dr H T Randall It was found that hypotonic glucose or starch meals given by mouth produced an immediate elevation in hematocrit diminution in plasma volume, and certain electrocardiogram changes There was some weakness uneasiness, and sweating Similar type of volume of food placed through the gastrostomy produced none of these symptoms or laboratory changes *This particular patient despite his mild disagreeable sensation* ate well and gained 20 pounds in six months although other patients with similar setups have

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*Rienhoff W F, Jr Intrathoracic Esophagojejunostomy for Lesions of the Upper Third of the Esophagus South M J 39 928 940 1946 had difficulty in regaining weight Therefore, it may be well worth while to consider attaching the lower end of the jejunum to the stomach and attempting to keep the retrosternal segment of jejunum as short as possible

DR LEWIS H BOSHER, Richmond, Va —We have employed esophagojejunostomy or esophagocologastrostomy in the treatment of lye strictures which failed to respond to dilatation or which could not be dilated We have used the anterior mediastinal route described by Dr Ross Robertson This has proved satisfactory even in small children

If the jejunum is used for reconstruction, we believe the procedure should usually be done in two stages, elevating the jejunum through the anterior mediastinum at the first stage and performing anastomosis at the second stage In the case of a long jejunal limb the cephalad end of the jejunum is usually quite edematous and shows some evidence of reduced blood supply If the jejunum is elevated high into the neck, there may be enough tension on the vascular arcade to lead to thrombosis and subsequent gangrene or atrophy of the cervical portion If the cervical portion appears dusky at the time of the first stage it should probably be returned to the superior mediastinum to await the second stage The second stage is carried out seven to ten days later The jejunum may be fished out of the superior mediastinum by the cervical approach or by separate anterior thoracotomy At that time the distal vascular arcade is divided in one or more places which easily mobilizes 6 to 8 inches of additional jejunum Between the first and second stages a rich intramural blood supply has developed which adequately nourishes the upper end of the jejunum

In some patients the jejunum sloughs after the initial procedure It is possible by doing simultaneous laparotomy thoracotomy, and cervical incisions to remobilize the jejunum without dividing any additional mesenteric vessels, and perform a pharyngo jejunostomy The upper portion of 6 or 8 inches of the jejunum can be nourished by intramural blood supply

In one child who had a complete lye stricture the jejunum was elevated and anastomosed Between the first and second stages the jejunum was allowed to remain in the superior mediastinum and at the second stage the vascular arcade was divided and an adequate portion easily elevated A technique we have used to divide the vascular arcade at the second stage easily mobilizes 6 to 8 inches of jejunum

We have also employed esophagocologastrostomy elevating the transverse and ascending colon The blood supply of the colon tube seems to be well maintained and we believe this procedure can be carried out in one stage Barium is apparent on the colon tube which has been anastomosed to the stomach in its distal portion

DR F S GERBASI, Long Beach Calif —I should like to relate the experiences at the University of Michigan in congenital strictures in infants and children There have been 14 cases of congenital stricture in the past twenty five years 10 in males and 4 in female All except one had the stricture between the middle and lower third of the esophagus None of the patients had symptoms before they were 15 days old This is in contradistinction to what we read about most of the literature says that symptoms come on when they start to eat semisolid foods None of the infants was premature We had 8 patients whom we were able to study early in their treatment and to show that they did not have a hiatus hernia However later in their treatment 3 of them did have a hiatus hernia Of 11 cases which we were able to follow, 5 developed a hiatus hernia All of the 11 cases had been treated with dilatations and only 4 had benefited I agree with Dr Holinger that these infants with congenital stenosis should be given a trial with dilatation If they do not respond I think the stenotic area should be resected early before they acquire esophageal change and a hiatus hernia

DR ROSS ROBERTSON Vancouver B C —I should like to try to answer Dr Potts' question by describing two patients with lye strictures treated by reconstruction of the esophagus by a jejunal transplant in the anterior mediastinum One following a al transplant had perforation from peptic ulceration of the stomach and in his case since nutrition was excellent, we did a complete gastrectomy He has carried on since without any dumping syndrome or other difficulty and has maintained good nutrition. The other patient was a young woman who complained bitterly of dumping syndrome In her case we did a partial gastrectomy, removing most of the acid bearing portion of the stomach and anastomosed the jejunum to the stomach She has been quite well since the *operation and has no discomfort after meals In both cases we had the problem of the* residual esophagus but since the mucosa was completely destroyed we left it in, it has given no trouble

DR PAUL H HOLINGER (Closing) —We appreciate the discussion on this subject Of course we would like to believe that when a child or an adult is operated on for a benign stricture he is cured But when he requires dilatation after operation just as before, we wonder and he wonders why the operation was done Most of the surgical failures we have seen particularly those operated on elsewhere and later referred for dilatation, followed removal of the stricture and gastroesophageal anastomosis, that is the most important point we found in our survey of postsurgical strictures Unfortunately this simple stricture removal and anastomosis is the procedure which is most often used and which seems logical when one looks at the roentgenogram and visualizes the picture that could be obtained by cutting out the stricture I think the discussion has been extremely helpful in pointing out that simple resection of the stricture is obsolete unless it is associated with some operation which will reduce the acid secretion of the stomach and that *while such operations are more complicated they give results which seem much* more favorable

DR WILLIS J POTTS (Closing) —I must apologize for not calling attention to Dr Rienhoff's work Many years ago he advised intrathoracic jejunoesophagostomy for malignancies of the esophagus

A METHOD OF PREVENTING PEPTIC ESOPHAGITIS FOLLOWING ESOPHAGOGASTROSTOMY

EXPERIMENTAL AND CLINICAL STUDY

DAVID H. WATKINS, M.D. (BY INVITATION), ARTHUR PREVEDEL, M.D. (BY INVITATION), AND FRED R. HARPER, M.D.
DENVER, COLO.

TO ENSURE the aboral transit of food from the esophagus into the stomach the junction between these two organs is augmented by a group of structures known collectively as the cardiac mechanism. This mechanism includes the valvular device at the cardiac orifice and the diaphragmatic pinchcock action of the right crus of the diaphragm at times of increased strain. The valvular mechanism of the cardiac orifice, or the "hiatal valve," consists of the synergistic action of the oblique inosculation of the esophagus into the stomach and the difference in pressure between that in the stomach and the intraluminal pressure of the esophagus.

Some regurgitation undoubtedly occurs as a physiologic process during swallowing and during or after the taking of food. Regurgitation is prone to occur when intraluminal esophageal pressure falls below intragastric or intra-abdominal pressure. The intra-abdominal pressure is increased by diaphragmatic and abdominal wall contraction. Contraction of the diaphragm also produces a decrease in intrathoracic pressure. Variations in intrathoracic pressure are transmitted to the esophageal lumen.[1] The intraluminal pressure of the esophagus is negative except during rises in intrathoracic pressure and following peristaltic waves. Under such circumstances the continuous reflux of stomach contents would be expected. However, the "hiatal valve" explains how food can pass from the esophagus into the stomach even if the intragastric pressure is higher. The peristaltic wave offers the increment in energy to increase the intraluminal esophageal pressure to a level above that in the stomach. The valve then opens and the bolus enters the stomach. When the increment in pressure produced by the peristaltic wave passes off the intragastric pressure becomes higher than the intraesophageal and the valve closes.

Donnelly[2] has shown that during inspiration the intraesophageal pressure is decreased and intragastric pressure increased. In deep inspiration also the descending diaphragm increases the angle of entry of the esophagus into the stomach. These factors would tend to decrease the competence of the valve. However, a column of barium is held up a considerable distance above

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the cardiac orifice during deep inspiration by action of the "diaphragmatic pinchcock." This pinchcock action is produced by increased tone of the right crus of the diaphragm. It comes into play with any increase of intra-abdominal pressure.

If this cardiac mechanism becomes disturbed by a pathologic development such as esophageal hiatal hernia, or by surgical means such as cardioplasty or esophagogastrostomy for obstructing lesions at the esophagogastric junction, certain undesirable secondary effects make their appearance. Surgical procedures which eliminate the cardiac mechanism are followed by repeated regurgitation of gastric juice into the esophagus. The resulting peptic esophagitis in turn may give rise to any of the generally known complications of peptic ulceration: hemorrhage, perforation, or obstruction. If the gastric juice is increased in amount or in relative acidity, the tendency to peptic ulceration is even more pronounced. It has been recently shown that normal gastric juice of normal acidity and enzyme content may produce peptic ulceration in the presence of an esophageal hiatal hernia without any primary anomaly of the secretory process itself.[3]

The appearance of peptic esophagitis following esophagogastric anastomoses has been extensively reported. In a series of 26 cases of cardiospasm treated surgically, Barrett and Franklin[4] observed the development of esophagitis with stricture formation in almost all cases. In a series of 121 gastroesophageal obstructions which were resectable, Allison and Borrie found that peptic esophagitis resulted in a large number of postoperative strictures, even though the vagus nerves were completely resected. Ripley and associates[6] in a series of 65 patients who were subjected to esophagogastrostomy or cardioplasty observed 28 with positive signs and 12 with presumptive signs of peptic esophagitis or stricture formation. Similar experiences have been reported by Nissen.[7]

The majority of these cases of inflammatory stenosis can be explained by the action of acid-peptic gastric juice in the lower esophagus. The evidence for such an explanation is the demonstration that gastric juice can gain access to the esophagus and once in this location will produce an inflammatory lesion. The erosive effect of gastric juice on the esophagus has been demonstrated by Ferguson and associates[8] and by Wangensteen and Leven.[9] Reflux of gastric content into the esophagus occurs clinically, especially in the presence of gastrointestinal pathology such as gall bladder disease or peptic ulcer.[10, 11] An association of esophagitis and stenosis with conditions allowing the frequent contact of gastric juice with the lower esophagus has been demonstrated.[12-14]

In 1951 Kiriluk and Merendino[1] reported a series of 18 animals in which 50 per cent proximal gastrectomy including the terminal centimeter of esophagus with restoration of gastrointestinal continuity by esophagogastrostomy was carried out. Supplementary procedures included pyloromyotomy, pyloroplasty, and preservation of the gastric pouch. Spontaneous complications of esophageal ulcer with perforation and massive hematemesis or melena accounted for 50 per cent of the deaths in the animals in an average of 45.5 days. In a more recent report[16] these same investigators related an experience with 21 dogs subjected to a 50 per cent proximal gastrectomy. In addition to this, ancillary procedures included bilateral vagotomy, gastrojejunostomy, anterior and posterior esophagogastrostomy, "preservation" of the vagi nerves, and the formation of a valvelike esophagogastrostomy. Sixty-two per cent of this series of animals died of spontaneous esophageal complications in an average of 56 days. Of 13 dogs which included 5 from the earlier series, all of which had survived for three or more months postoperatively, only 5 exhibited normal esophagi by esophagoscopy. In this series the creation of a valvelike esophagogastrostomy and the "preservation" of the vagal nerves were the only supplemental procedures which suggested a protective effect in preventing esophageal complications. The valve in this case was of the "fish mouth" type.

METHOD

Regurgitation and belching are common physiologic events in normal men and dogs and demonstrate that the cardiac mechanism is a reversible one which may be incompetent normally at times. The normal "hiatal valve" depends upon the obliquity of insertion of the esophagus into the stomach wall together with a mechanical arrangement which permits the approximation of the walls of the esophagus by the intragastric pressure which, in the absence of a peristaltic wave traveling down the esophagus, tends to obliterate the lumen and to prevent regurgitation. Thus the concept was formulated that perhaps a plastic procedure on the distal esophagus could be performed which would more nearly approximate the functions of the normal "hiatal valve" than a simple end-to-side or end-to-end esophagogastrostomy.

Healthy adult mongrel dogs weighing from 30 to 60 pounds were used. Six such animals were subjected to the procedure. Both vagal nerves were preserved. The esophagus was transected 1 cm. above its inosculation into the stomach and the cardia was transected about 1 cm. below. This wound was then closed. Esophagogastrostomy with the formation of a valve was carried out in end-to-side fashion. The technique used is illustrated in the accompanying diagrams (Figs. 1-5). Thus the esophagogastrostomy in each case lies above the level of the diaphragm in the posterior mediastinum.

EXPERIMENTAL RESULTS

The results are summarized in Table I.

All esophagoscopies were carried out under general anesthesia. Mild esophagitis was indicated by erythema of the mucosa. No ulceration or stenosis was noted in any of the preparations. The dogs ate well. Some, however, did not relish the laboratory diet, the loss of weight in one case is attributed to this.

On April 1, 1951 all the dogs were studied by fluoroscopic examination following the introduction of a barium meal into the upper esophagus. In all cases the barium passed easily through the "hiatal valve" into the thoracic portion of the stomach (Fig. 6). With the animal held at a 90 degree angle with the head downward, a small amount of barium regurgitated into the esophagus. In this case, however, the main mass of the barium was retarded from passing into the esophagus by a marked contraction of the diaphragm (Fig. 7). We have termed this phenomenon "diaphragmatic impedance."

Dog 4 died 118 days following operation. The diaphragmatic wound had been sutured with too fine suture material and dehiscence occurred with strangulation of small intestine. The specimen shows the end result of the procedure (Figs. 8, 9).

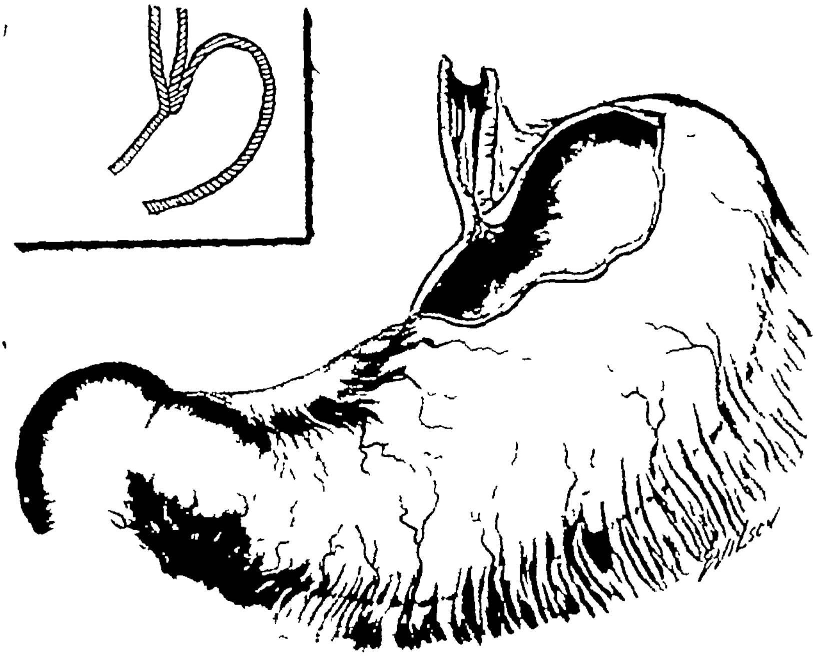


Fig 1 —The normal cardia is closed by the hiatal valve The mucosal lips are approximated by the intragastric pressure which exceeds the intraesophageal pressure.

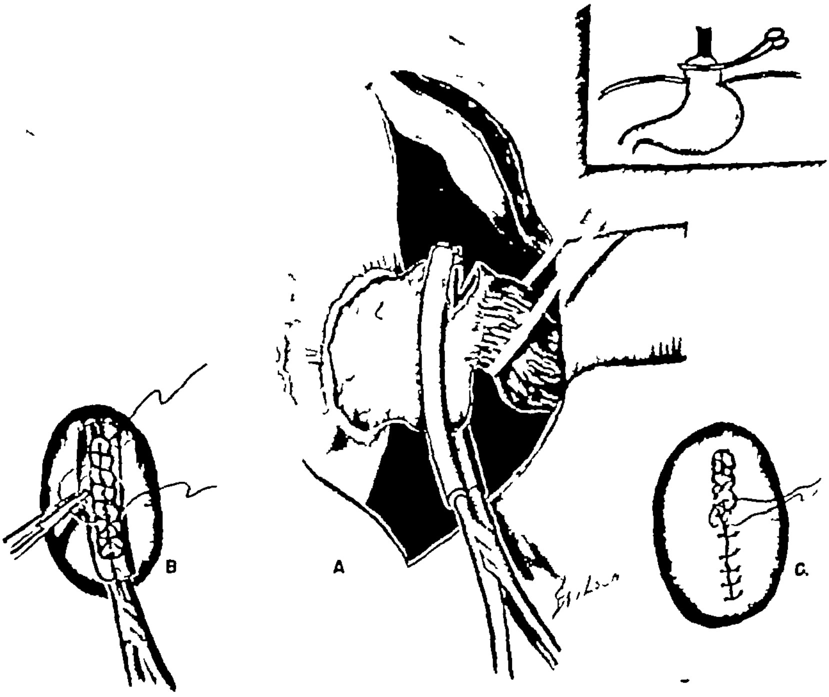


Fig 2 —A The cardia and the distal 1 cm of esophagus are excised B and C The cardiac orifice is closed

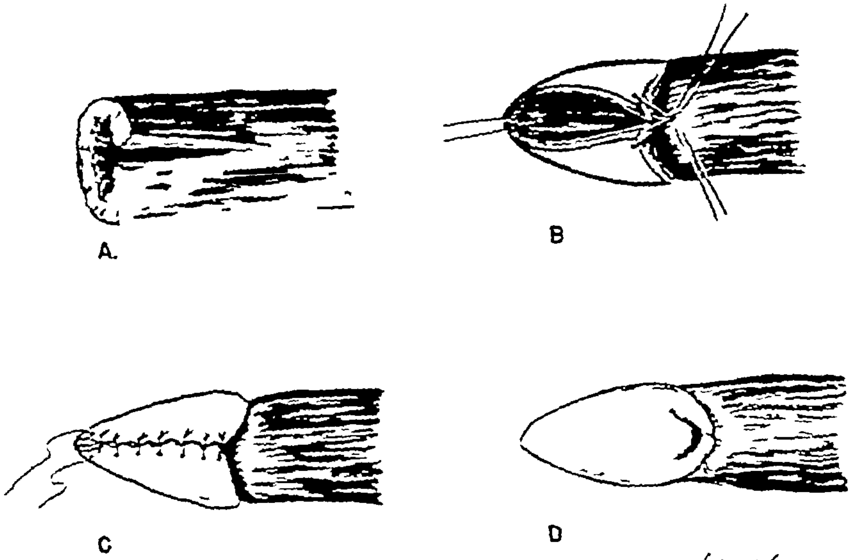
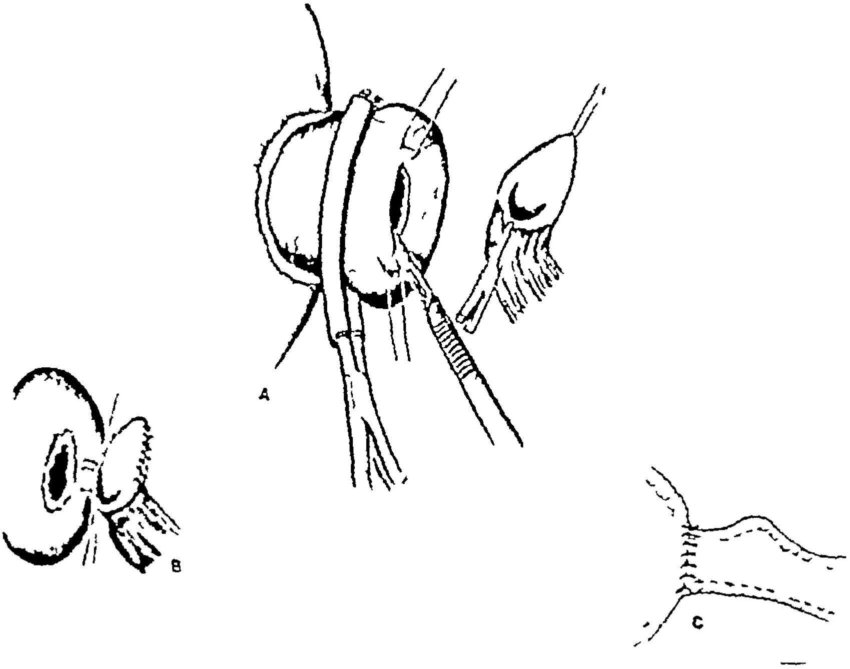


Fig. 3.—A. The esophagus is slit for a distance of [illegible] cm. B, C. The cut edges are rotated 180° and approximated. D. The completed valve is now ready for implantation.



[illegible] placed with valve [illegible] implanted into buttonhole stoma of stomach. B. [illegible] approximation results. C. Insert shows [illegible] anastomosis.

TABLE I

DOG NO.	INITIAL WEIGHT (LBS.)	DATE OF OPERATION	IMMEDIATE POSTOPERATIVE STATUS	DATE	RESULTS OF ESOPHAGOSCOPY	FINAL WEIGHTS (LBS.)	SURVIVAL IN DAYS POSTOPERATIVELY
1	45	8/21/53	Vomiting for 3 days	10/ 5/53	Slight esophagitis, moderate reflux		
				12/23/53	No esophagitis, slight reflux		
				2/11/54	Negative		
				4/11/54	Negative	42	234
2	42	9/16/53	Vomiting for 3 days	10/ 5/53	Slight esophagitis, slight reflux		
				12/23/53	Slight esophagitis, slight reflux		
				2/11/54	Slight esophagitis, slight reflux		
				4/11/54	Slight esophagitis, slight reflux	32	208
3	34	10/ 8/53	Vomiting for 3 days	12/23/53	No esophagitis, slight reflux		
				2/11/54	No esophagitis, slight reflux		
				4/11/54	No esophagitis, slight reflux	37	186
4	36	11/20/54	Vomiting for 3 days	12/23/53	Negative		
				2/11/54	Negative	35	118 (died of strangulated traumatic diaphragmatic hernia)
5	30	1/ 4/54	Vomiting for 3 days	2/11/54	Slight esophagitis, moderate reflux		
				4/11/54	Slight esophagitis, moderate reflux	30	98
6	60	2/ 8/54	Vomiting for 3 days	2/24/54	Slight esophagitis, moderate reflux		
				4/11/54	No esophagitis, slight reflux	55	63

CLINICAL APPLICATION

Because of the encouraging results derived from the animal experiments, essentially the same type of valvular esophagogastrostomy was carried out in the following clinical cases.

CASE 1.—E. F. M., a 68-year-old white woman, entered the hospital Sept. 24, 1953, with complaint of dysphagia since January, 1953. Since that time she had been troubled with regurgitation and had lost 70 pounds. At the time of admission she was able to take only liquids.

Examination demonstrated a chronically ill woman with marked evidences of profound weight loss. She was moderately dehydrated. Her blood pressure was 140/86, pulse 88, respirations 22. The liver edge was palpable 5 fingerbreadths below the costal margin

Urinalysis was negative except for a few granular casts. Examination of the blood showed the hemoglobin to be 1[illegible] Gm. The erythrocyte count was 4.6 million. The leukocyte count was 7,000 with a normal differential count.

Esophagoscopy demonstrated a lesion 25 cm above the cardia and examination of tissue removed by biopsy showed adenocarcinoma of the stomach with extension to the esophagus. Operation was carried out Oct 20 1953. A left posterolateral thoracotomy incision was made removing the eighth rib subperiosteally. A large very fixed hard mass involving the proximal four fifths of the stomach was found; obvious metastases to the gastro[illegible] lymph nodes and the left gastric pedicle were present. The esophagus was mobilized by incising the mediastinal pleura up to the inferior pulmonary vein. The left gastroepiploic vessels were ligated and the spleen was mobilized and removed. The stomach was mobilized along the greater and lesser curvatures to the duodenum. The

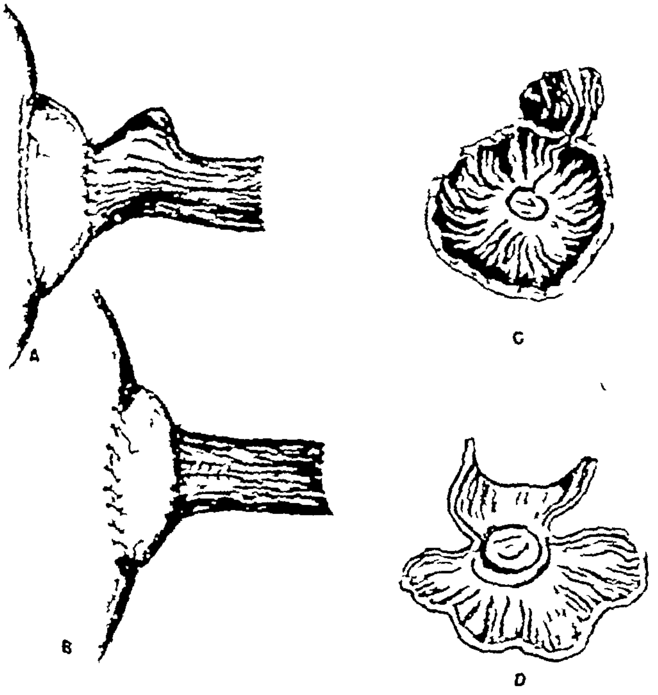


Fig. [illegible] If [illegible] the valve may be pushed into the lumen of the esophagus to [illegible]. B, Then the valve is pushed into stomach using a small slit in the [illegible] which [illegible] sutured. C, Upon completion of the procedure the valve almost [illegible] in the resting esophagus. D, The protruding mushroom of the [illegible]

stomach was transected obliquely in its distal portion allowing a considerable part of the [illegible] curvature to remain. The esophagus was next transected leaving a margin of 3 [illegible] the [illegible] proximal extent of the tumor. A valvular esophagogastrostomy of the type described was carried out implanting the esophagus into the distal gastric [illegible] a button of gastric wall and anastomosing the esophagus to the [illegible]. The gastric [illegible] to the parietal pleura with interrupted suture.

Her postoperative course was very satisfactory. She was able to swallow satisfac[illegible] with no difficulty. During the immediate postoperative [illegible] easily controlled by bismuth and paregoric. In [illegible] of the fact that [illegible] of the malignancy had been carried out she [illegible] with regurgitation or dysphagia.

An upper gastrointestinal series Nov 23, 1953 showed a nicely functioning valvular anastomosis with an artificial hiatus hernia (Figs 10 and 11). There was no appreciable reflux back into the esophagus in the recumbent Trendelenburg position. Following her dismissal from the hospital she got along reasonably well but failed to gain weight. Repeated esophagoscopies failed to show evidence of esophagitis.

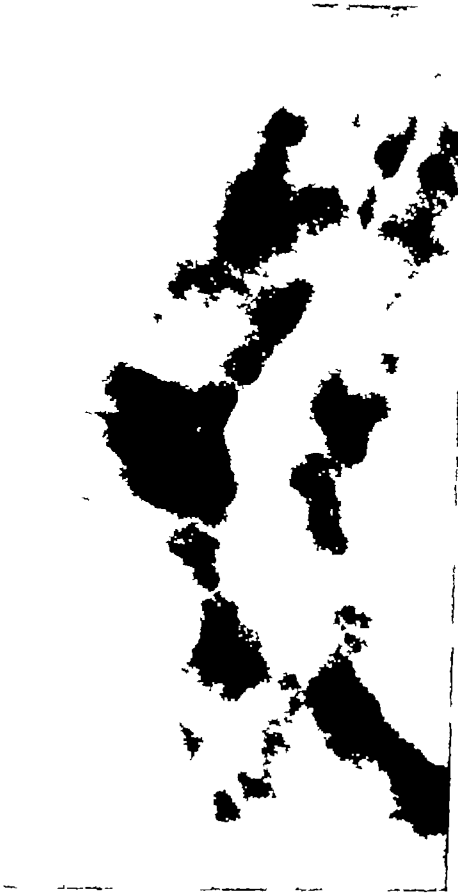


Fig 6

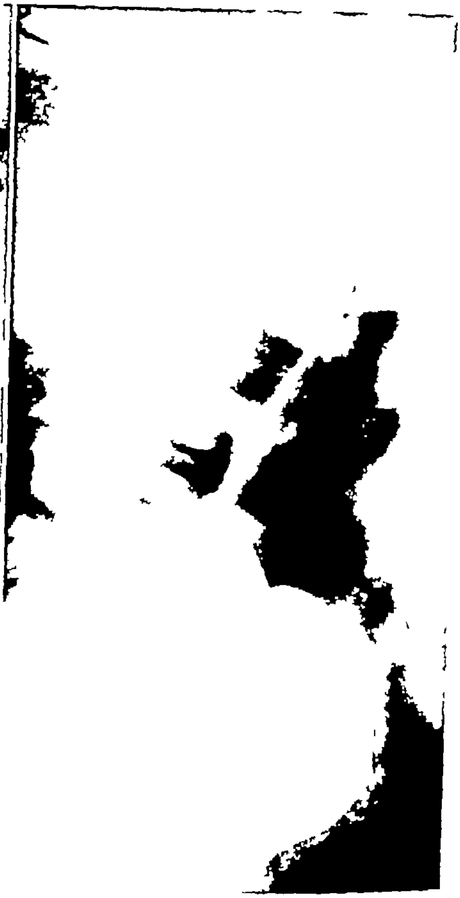


Fig 7

Fig 6.—Roentgenogram shows the valve at the junction of esophagus and intrathoracic portion of the dog's stomach.

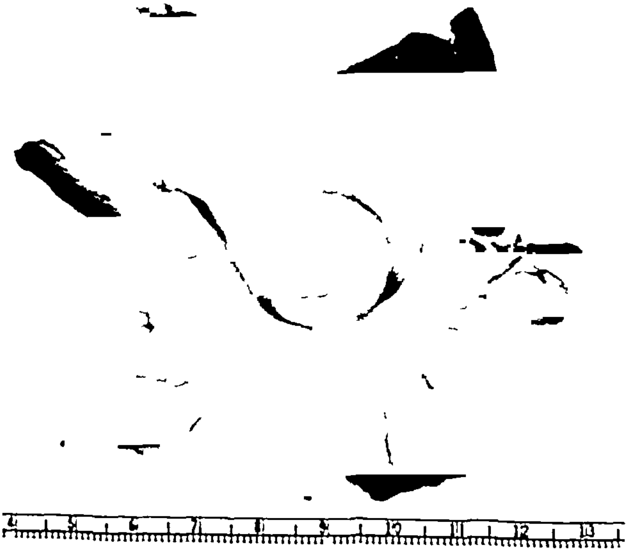
Fig 7.—Roentgenogram of dog held head downward following ingestion of barium meal. Little barium regurgitates into the esophagus; most of it is held back by diaphragmatic impedance.

Case 2.—T. T. T., a 68 year old white man, entered the hospital on Sept 2, 1953 with the complaint of dyspnea for four years and regurgitation of food for one month. He had developed a progressive increase in dyspnea during the preceding month and had periodic precordial pain. During the preceding month he had been unable to swallow any solids and upon admission he was unable to take even water.

Examination disclosed a poorly nourished white man in respiratory distress and appearing chronically ill. Blood pressure was 95/75, pulse 88, *respirations 44 and irregular*. The neck veins were distended. Examination of the chest showed a marked increase in the anteroposterior diameter. The lungs were hyperresonant and the breath sounds were decreased in intensity A systolic murmur was present over the apex P was greater than A The liver extended 4 cm below the costal margin and was not tender

The urinalysis was negative on admission Examination of the blood demonstrated a hemoglobin of 16 Gm the white blood count was 13 600 with a normal differential count Total blood proteins and the albumin globulin ratio were normal The serology was nega

Fig 8



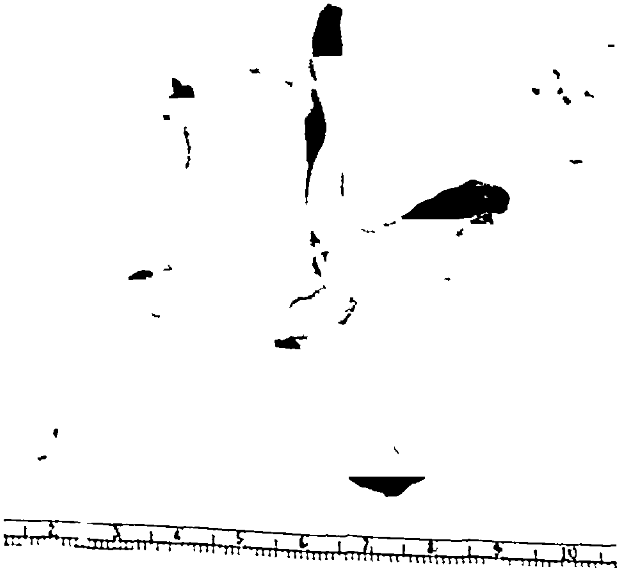
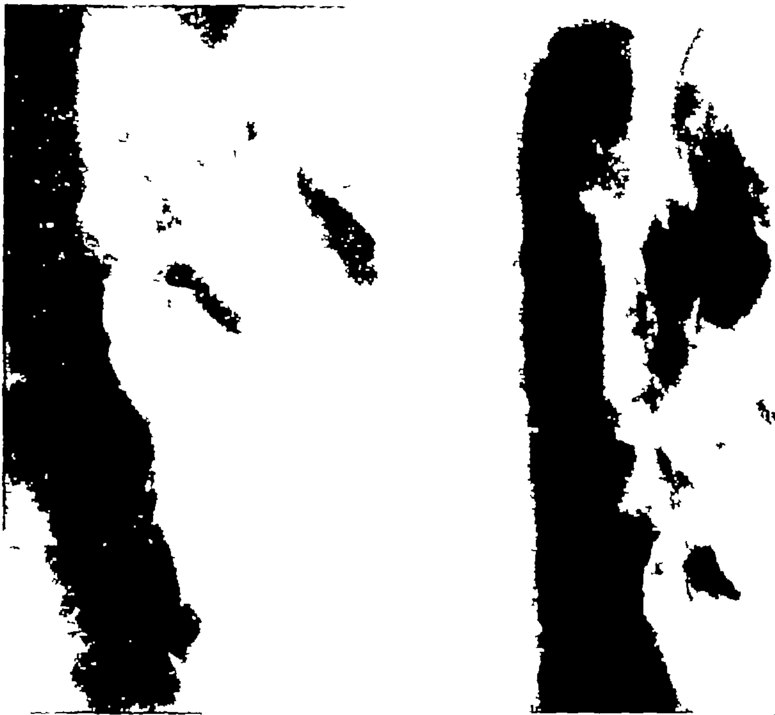


Fig 9

Fig 8 Specimen showing invagination of [illegible] phagus into stomach There is no evidence of [illegible] The mucous membrane projection of the valve is seen

Fig 9 When the walls of the [illegible] esophagus are approximated the valve is seen to [illegible] the stomach

Fig 10



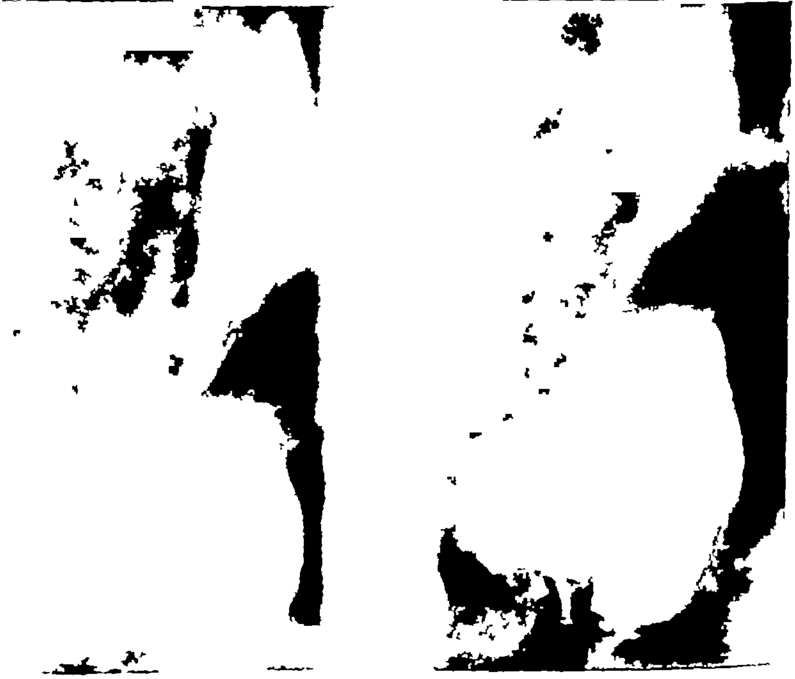


Fig 11

Fig 10.—L. F. M. The esophagus enters the stomach via a valvular mechanism

Fig 11.—L. F. M. The artificial hiatal valve is seen to open when a peristaltic wave carrying a barium bolus arrives at the stomach

tive. An electrocardiogram showed a normal sinus rhythm with marked clockwise rotation consistent with cor pulmonale. A roentgenogram of the esophagus showed a marked obstruction in the esophagus at a point 18 cm. proximal to the cardia. This obstruction was seen to be irregular and extended over an area of approximately 8 cm. of the lower half of the esophagus.

Esophagoscopy on September 8 demonstrated an obstruction in the middle third of the esophagus. The obstruction consisted of globular pedunculated growths producing almost complete obstruction. Microscopic examination of tissue removed for biopsy demonstrated a squamous-cell carcinoma of the esophagus.

Operation was carried out on Sept. 23, 1953. In spite of the fact that the patient had severe pulmonary emphysema and arteriosclerotic heart disease requiring digitalis, it was felt that exploratory thoracotomy should be undertaken.

A left thoracotomy was performed through the bed of the eighth rib. The lung showed chronic fibrosis with a few scattered subpleural blebs. The posterior mediastinum was opened and a cancer of the esophagus measuring 10 cm. in length and fixed markedly in the posterior mediastinum was demonstrated. The esophagus was freed from the pulmonary hilus. The lesion extended so high that transection above the aorta was mandatory. Because it was impossible to remove all of the involved esophageal nodes bilaterally, this procedure was considered to be only a palliative operation justified by the absolute dysphagia. The diaphragm was opened from the esophageal hiatus outward through the central tendon and the stomach was mobilized along the greater and lesser curvatures, ligating the left gastric and left gastroepiploic vessels but leaving the spleen intact. The esophagus was cut across at the cardia approximately 6 cm. below the palpable lower edge of the lesion and the cardia was closed. The stomach was sufficiently mobilized so that it could be easily drawn up into the left hemithorax. The esophagus was transected at a point 4 cm. above the superior edge of the lesion and removed. The posterior border of the esophagus was incised for a distance of 3 cm. and a valve was constructed, approximating the edges posteriorly with interrupted sutures so that the distal portion of the esophagus to be anastomosed into the side of the stomach had an introitus diagonal in direction and considerably smaller than the full lumen of the esophagus. Esophagogastrostomy was then carried out, approximating the mucosa of the esophagus and stomach. A plastic tube was threaded through the anastomosis well into the stomach and the stomach was fixed to the thoracic wall with interrupted silk sutures. The diaphragm was reconstructed and the chest wall closed in layers.

Comment.—The applicability of this procedure is illustrated by these two cases. In the first case the lesion was situated in the cardiac portion of the stomach and in the lower third of the esophagus. It is in this group of cases of esophagogastric anastomoses (esophagogastrostomy, cardioplasty, etc.) that so many poor results have occurred.

In the second case the lesion was situated in the midportion of the esophagus and anastomosis was required above the level of the aortic arch. The procedure of valvular esophagogastrostomy was easily carried out in this case.

DISCUSSION

Valdoni has demonstrated the worth of a valvular type of esophagogastrostomy in high anastomoses. In his cases the resections of the stomach and esophagus were carried out by a preliminary supraumbilical median laparotomy followed by a right thoracotomy. After the stomach pouch had been drawn up into the right hemithorax, a terminolateral anastomosis was made between esophagus and stomach. Thus the long axis of the esophagus was oblique with respect to the long axis of the displaced stomach In this procedure, then, one component of the "hiatal valve," the oblique insertion of the esophagus into the stomach, is utilized However, this procedure is restricted to high esophageal resections with the stomach being placed in the right hemithorax It cannot be applied to lesions in the lower third

The normal mechanism to prevent the regurgitation of food into the esophagus is a valvular one situated at the cardiac orifice and called the "hiatal valve" The two components of this valve are the oblique insertion of the esophagus into the stomach and the difference in intraluminal pressures of the two viscera which approximates the mucosal lips of the cardia Our procedure imitates these features of the normal cardiac orifice Further in the normal person with deep inspiration, the descending diaphragm increases the angle of entry of the esophagus into the stomach as well as increasing the intragastric pressure These factors would tend to decrease the competence of the valve However, in this circumstance the "diaphragmatic pinchcock" affords an additional hindrance to regurgitation This is produced normally by the right crus of the diaphragm In our dogs and patients operated upon this same effect which we have called "diaphragmatic impedance occurs

The efficiency of our valvular anastomosis has been demonstrated by repeated observations of our experimental animals and patients Further, the ease and applicability of this procedure to both high and low esophagogastrostomy are of considerable advantage

Although this communication must necessarily be a preliminary report and although we have restricted the use of the procedure so far to cases of proved malignancy, it is our hope that it may find more extensive use in being applied to benign lesions of the esophagus especially those occurring in the lower third We hope that it may find application to cases of peptic ulceration and stenosis of the lower third of the esophagus associated with short esophagus and hiatal hernia

CONCLUSIONS

1 Valvular esophagogastrostomies were carried out in dogs in which the entire stomach pouch was preserved

2 These dogs have survived without evidences of appreciable esophagitis for periods varying from 63 to 234 days and were still living at the time of this report

3 This procedure has been carried out in human patients with encouraging clinical and roentgenologic results It has the advantage of being applicable to both high and low esophagogastrostomies

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DISCUSSION

DR ALFRED HURWITZ West Haven Conn—I should like to compliment Dr Watkins and his group on their ingenious method of constructing esophageal valves I think they will have to have a long follow up of these patients however before they will be able to determine whether they can emulate the intricacies of Nature so far as the construction of valves in this region is concerned

With regard to the type of anastomosis we have felt that esophagojejunostomy offers much more than esophagogastrostomy in the prevention of the factor of acid regurgitation I think we are all agreed that acid regurgitation is the *bete noire* in the problem that faces us viz the development of esophagitis and later stenosis We have had gratifying experience with nine patients who have had esophagojejunostomy, experiences that have been described in the past by Allison of Leeds and Barnes at the New York Hospital Two of the patients are living for five and seven years after operation are completely well and are able to ingest at one sitting as much as any average adult male

Two patients have had an anastomosis by an end to side esophagojejunostomy with an enteroenterostomy One patient had had a splenectomy in 1946 for a Banti syndrome with esophageal varices which were bleeding markedly at that time In 1952 because of recurrent bleeding I performed a portocaval anastomosis which gave him a remission for one year followed by two bouts of severe bleeding Approximately six months ago through a left thoracoabdominal incision the pressure was determined in the gastroepiploic vein and found to be 180 mm of saline The lower 3 inches of the esophagus and the upper third of the stomach were resected the gastric pouch was closed and left behind Whether we should have done a pylorotomy remains to be seen but it was [illegible] A Roux en Y anastomosis was performed We feel that this procedure has three advantages as far as treatment of esophageal varices is concerned First the area which is [illegible] vulnerable to ulceration and in which the varices usually bleed [illegible] the acidity is cut down both by the bilateral vagotomy and removal of [illegible] portion of the proximal part of the stomach Third the en Y anastomosis [illegible] regurgitation into the esophagus I feel that this may be ap plied not only as a secondary procedure in cases where shunts have failed, but possibly as a primary procedure where it has been determined that the factor of acid digestion is more prominent than the degree of portal hypertension

DR JOHN H GARLOCK, New York, N Y—I want to congratulate the authors on this rather ingenious procedure It may turn out to be the answer to some of the difficulties we encounter following resections for benign lesions of the lower esophagus I would like to emphasize that it is important to make a very sharp distinction between esophagogastric resections for malignancy and benign lesions, especially strictures following esophagitis In this connection, may I call your attention to some physiologic studies which were made on my service at Mt Sinai Hospital by Dr Dreiling, Dr Druckerman, and Dr Hollander on the secretory function of the stomach and pancreas following radical resection for carcinoma of the esophagus and cardia Their paper was published two years ago in GASTROENTEROLOGY

They studied ten patients taken at random from a large group that had had radical resections for malignant neoplasm It is interesting to note that in every instance but one there was complete anacidity The one exception, a patient who had had a carcinoma of the middle third of the esophagus, showed a combined acid figure of 42 units After the Hollander insulin test it was found to be zero It is important to differentiate this group of patients from those who have reflux esophagitis following resection for benign lesions We have not been bothered in any way by reflux esophagitis in the carcinoma group When stricture developed at the anastomosis in the early days of our experience, it was found to be due to the use of a continuous suture in making the anastomosis This complication has been obviated since interrupted sutures were introduced Latterly, our experience has been that, when a stricture develops at or near the suture line it has been found to be caused by a recurrence either at the suture line or in the posterior mediastinum Further experience and prolonged follow up will settle the efficacy of this new procedure I would hazard the guess that this newly created valve will undergo scar contraction as time goes on, and that its function will decrease the longer the patient is followed

DR DENTON A COOLEY, Houston, Texas—We, like many others, have been impressed with the difficult problem of erosive esophagitis which occurs after esophagogastric anastomosis *The bleeding and obstructive symptoms in such cases may lead to an entirely* unsatisfactory result of an operation which was otherwise curative for the original lesion The solution of this problem is vital if esophageal resection is to be employed more frequently and for benign as well as for malignant diseases Dr Watkins' presentation of a technical modification in the method of anastomosis is interesting in this regard but I doubt whether it will appreciably alter the situation particularly for anastomoses performed in the lower third of the esophagus Personally, I believe that the problem in the distal esophagus will be the same at the junction of acid secreting gastric mucosa with squamous epithelium, regardless of the attempts to reproduce a valvular mechanism at the anastomosis

During the past three years we have advocated extensive subtotal esophagectomy for practically all esophageal lesions irrespective of their anatomic level, and have reported on the results of this method of treatment* The rationale for this apparently radical attitude is based upon the clinical observation that postoperative esophagitis in the high anastomosis is very infrequent We have used this procedure for carcinoma, lye stricture, stricture from peptic esophagitis and for extensive varices, and no instance of postoperative esophagitis has been *encountered* *Jejunal transplants are, we feel, unsafe, and,* as already mentioned here today, there are certain late complications which make esophagojejunostomy undesirable When the stomach is transplanted into the thorax gastric drainage can be improved by concomitant pyloromyotomy and should be used routinely Restora tion of alimentary continuity with the normal progression of food and juices from esophagus to stomach to intestine is thus achieved without the complications of treatment associated with other methods

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*Dr Denton A Cooley Palliative Resection for Carcinoma of the Esophagus A M A Arch Surg 66 781 1953 Subtotal Esophagectomy for Bleeding Esophageal Varices A M A Arch Surg 68 851 871 1954

DR HERBERT W SCHMIDT, Rochester Minn —The marked reduction in mortality rates in thoracic surgical procedures has broadened the indications for operations on the esophagus An increasing number of operations are now being performed for lesions that involve the cardia Many of these lesions require excision of the cardia and this always causes an incompetency which allows free regurgitation of gastric contents into the distal part of the esophagus This condition at times produces peptic esophagitis and ulceration

Anything that can be done to prevent such a complication would be most worthwhile It will be interesting to see whether or not the procedure that Dr Watkins has described will completely solve this problem It will take time to be certain about this because the development of peptic ulceration may be slow Sometimes up to eighteen months may elapse before it becomes manifest

DR PAUL NEMIR, JR Philadelphia Pa —I have enjoyed Dr Watkins paper very much I would like to bring up one factor concerned with esophagitis following destruction of the esophagogastric junction mechanism which has not received a great deal of attention This factor was strikingly demonstrated in two patients who had achalasia of the esophagus of long duration In both conservative management was ineffective in relieving the symptoms and operation was therefore performed One of these was operated upon in 1948 and an esophagogastrostomy of the Grondahl type was performed The other was operated upon in 1950 and an esophagocardiomyotomy was performed Postoperatively, both developed severe esophagitis and on several occasions had severe hemorrhage Both patients had no free acid on gastric analysis On barium swallow both patients exhibited no delay in emptying at the esophagogastric junction but marked delay in emptying at the pyloroduodenal area Very little barium was found to leave the stomach even up to six hours Both had marked regurgitation from the stomach into the esophagus when placed in the Trendelenburg position on the fluoroscopic table In one of the two it was thought that a stenosing duodenal ulcer was accounting for the delayed emptying Operation was again performed on both patients No duodenal ulcer was found nor was there any gross evidence to account for the delayed emptying at the gastroduodenal area in either case A gastrojejunostomy was performed in one and a subtotal gastrectomy in the other Postoperatively both were completely relieved of their symptoms and gastric emptying was no longer delayed There have been no further hemorrhages I think in addition to the acid peptic factor the factor of delay or failure of normal emptying at the gastroduodenal area and the resultant regurgitation are also contributing causes to the esophagitis In these two cases despite no free gastric acid there occurred severe esophagitis and hemorrhage which was relieved by improving the gastric emptying

The delay in gastric emptying is difficult to explain It is highly unlikely that the vagus nerves were severed in either procedure We carefully examined the resected specimen of one and no gross lesion was found at the pyloroduodenal area The intrinsic [illegible] plexus was present As postulated with the esophagus however it may be that there is a [illegible] derangement of function of the intrinsic neural mechanism without necessarily anatomical [illegible] this [illegible]

DR I DARIN PUPPEL Columbus Ohio —Dr David Watkins and his group are certainly to be congratulated for this splendid piece of experimental and clinical work We have been interested in the difficult problem of bleeding esophagitis for a number of years [illegible] with Dr [illegible] Columbus Ohio and I had a patient 60 years old with [illegible] esophagitis and a [illegible] sliding hiatal hernia [illegible] severe anemia with a [illegible] content of [illegible] per cent This patient [illegible] of bleeding following a transthoracic transplantation operation [illegible] the diaphragm [illegible] back and in front of the esophagus thus [illegible] of diaphragm for about an inch

This tunnel seemingly acts as a sphincter, and no evidence of regurgitation or dysphagia has as yet been discerned. In the Trendelenburg position barium does not regurgitate from the stomach into the esophagus postoperatively. The red cell count is now 4.2 million and the hemoglobin 13.1 Gm. per cent.

For one case of bleeding esophagitis which occurred following an esophagogastrostomy with vagotomy and partial gastric sympathectomy, I did a posterior gastrojejunostomy two years later. This procedure led to better gastric drainage and also allowed mixture and neutralization of the acid gastric secretions by the alkaline secretions of the liver and pancreas. In this case bleeding has not as yet occurred following the gastrojejunostomy.

DR. J. L. EHRENHAFT, Iowa City, Iowa.—In the very occasional patient in whom one prefers to prevent regurgitation esophagitis or in whom a lower esophagectomy or total gastrectomy would be necessary, I believe a direct esophagoduodenostomy following total gastrectomy is a wise procedure. This end-to-end esophagoduodenostomy in some selected patients is feasible if the approach is through a left combined thoracoabdominal incision. Our experience with this is limited, but we were surprised at the ease with which a good end-to-end anastomosis between esophagus and duodenum can be established. This reduces the operating time considerably, does away with Roux-en-Y or loop esophagojejunostomies and also establishes a more physiologic gastrointestinal continuity.

DR. DAVID H. WATKINS (Closing).—I wish to thank the discussors for their remarks. With regard to Dr. Cooley's comment, if you do not have the esophagus you do not have peptic ulcer in the esophagus. Valdoni and others have shown over a period of some years that in the high gastroesophageal anastomosis, esophagitis is not a problem. He did his cases with a preliminary median supraumbilical laparotomy and then a right posterolateral thoracic incision. He attributed the good results in his cases to the fact that a type of valve was formed in the esophagogastrostomy which was done at this time. I think we must emphasize that this procedure is designed only for those cases in which it is desired to preserve stomach function. I personally always have had a deep attachment for that organ, particularly with regard to its function.

There is another possibility in those cases which require a total gastrectomy and the removal of a variable amount of the esophagus. In our hands at least, the best functional results have come from the use of a transplant of colon from the transverse and descending colon essentially according to a plan which was devised in 1908 by Dr. Archibald who demonstrated that the colon blood supply could be maintained if only one of the radial colon arteries is preserved along with the marginal vessels. I think in cases in which total gastrectomy is done that this is the proper procedure.

OPPORTUNITIES FOR RESEARCH IN THORACIC SURGERY WITH THE USE OF TISSUE CULTURE METHODS

C. M. Pomerat, Ph.D. (by invitation)*
Galveston, Texas

As indicated by its title, this report is directed at suggesting some of the many opportunities for research on the dynamic cytology of tissues found in the chest which are available with modern methods for cell culture. No fundamental questions will be resolved. Analyses of pathologic mechanisms will be touched upon only by means of a few citations from the literature and with a group of photomicrographs. The main evidence for the approach consists of a group of phase contrast time-lapse cinematographic sequences showing the activities of cells derived from the respiratory system of man. In short, the lecture represented by this paper consisted only of an invitation to research with the methods described.

MATERIALS AND METHODS

Workers in laboratories having facilities for cell culture as applied to problems of experimental medicine generally find it valuable to use a wide variety of methods. For the rapid screening of new drugs in the determination of toxicity, the use of small hanging drop slide preparations has been found particularly valuable.[1] Such preparations are also useful for short-term cultures of adult human epidermis[2] and nasal mucosa.[3] Epithelial outgrowth is favored by the addition of 3 to 4 drops of cell-free ascitic fluid of malignant origin onto an avian plasma clot containing the tissue explant. Maximow's double cover slip method for the cultivation of explants from surgical specimens has been described by Murray.[4] Carrel flask technique and its modification by Porter recently have been outlined by White.[5] Perhaps of widest general use is the roller tube method of Gey.[6] In our own experience the arrangement of several explants on the outer face of double cover glasses in roller tubes has proved especially useful for many types of experiments.

Excellent reviews are available concerning the suitability of various media and the rules for the replenishment of nutrients, the latest of which can be found in White's book. As an outgrowth of studies on the behavior of cell sediments in body fluids, our group has made extensive use of ascitic fluid, both malignant and nonmalignant in origin, as a medium constituent.[8] However, with the increased use of mercurial diuretics the supply not only has become less available but its chemistry is likely to be complicated. For those who favor the presence of human proteins in the fluid nutrient phase, human umbilical cord serum unquestionably remains the object of choice when an adequate quantity readily can be obtained.

Supported in part by a grant-in-aid from the American Cancer Society upon recommendation of the Committee on Growth of the National Research Council and in part by Office of Naval Research Contract No. Nonr-[illegible] T.O. [illegible]

Read at the Thirty-fourth Annual Meeting of The American Association for Thoracic Surgery at Montreal, Quebec, May 3 to 5, 1954.

*From the Tissue Culture Laboratory, The University of Texas Medical Branch, Galveston, Texas.

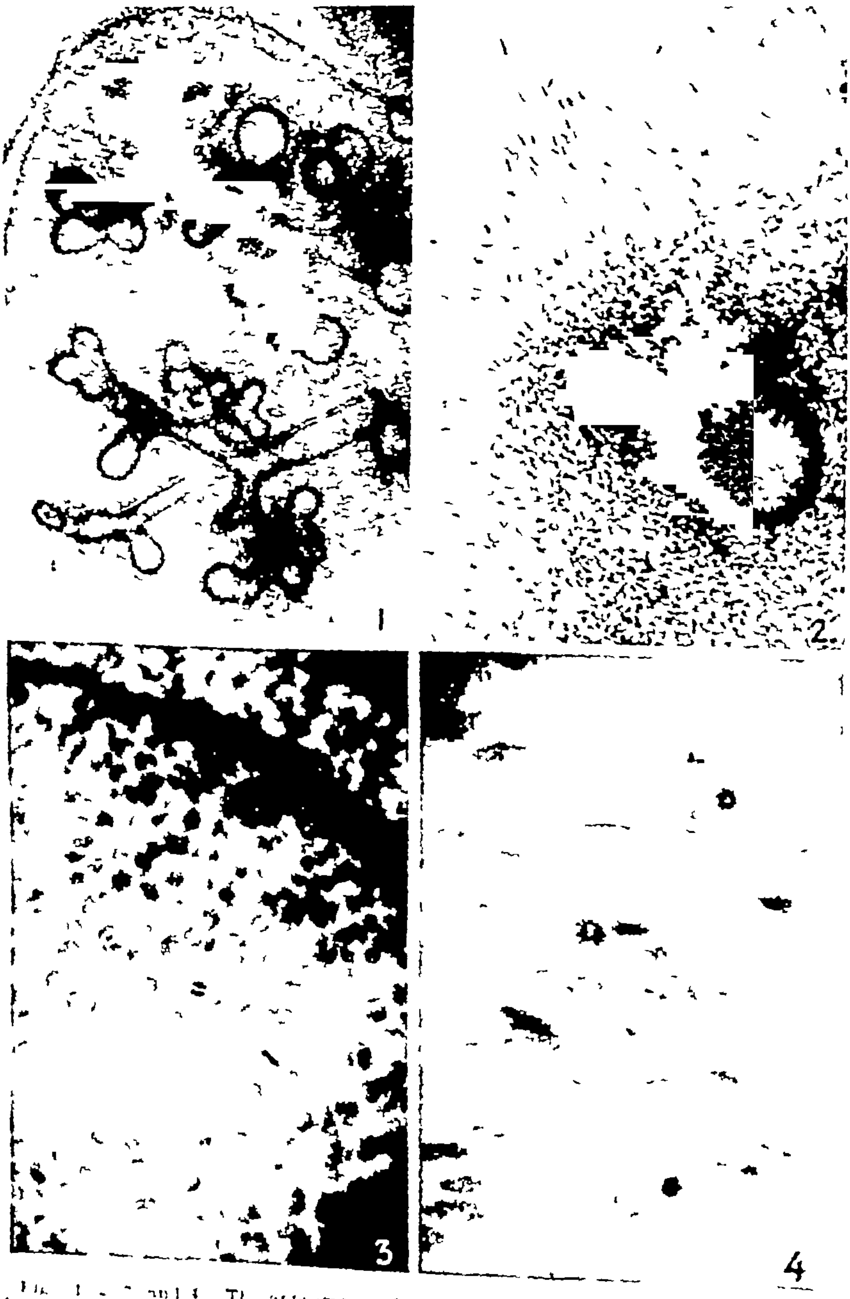
Staining procedures which have proved important in the study of culture preparations include diluted Delafield's hematoxylin, Jacobson's method,[9] Rio Hortega's double silver impregnation for reticular fibers and Polak's silver method for mitochondria.

The basic arrangement for a double camera assembly used in making phase contrast, time lapse cinematographic records, together with a device for perfusion of cultures has been described.[10] Cell activities and suggestions for their analysis from film records have been reported by Pomerat[11] and by Pomerat, Lefeber, and Smith.[12]

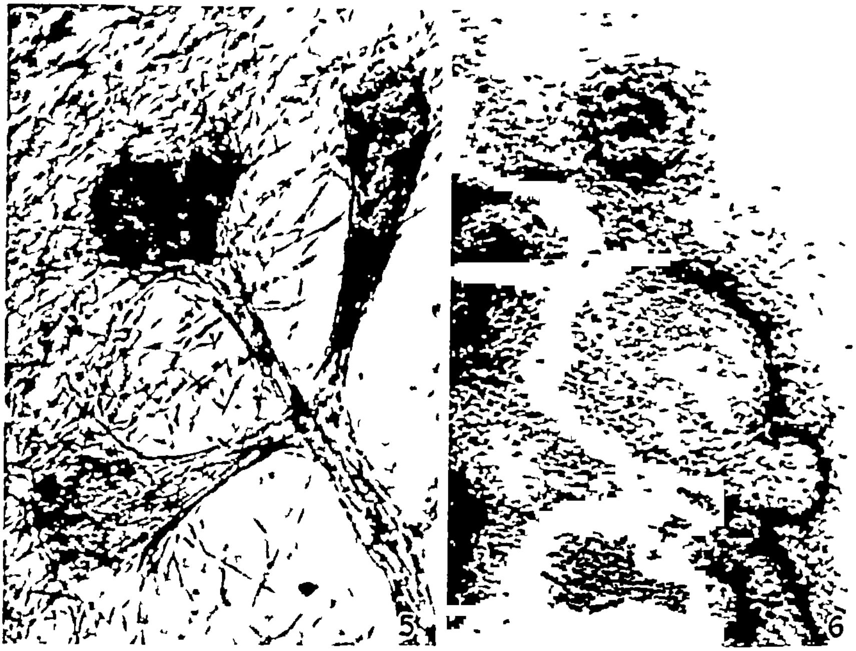
OBSERVATIONS

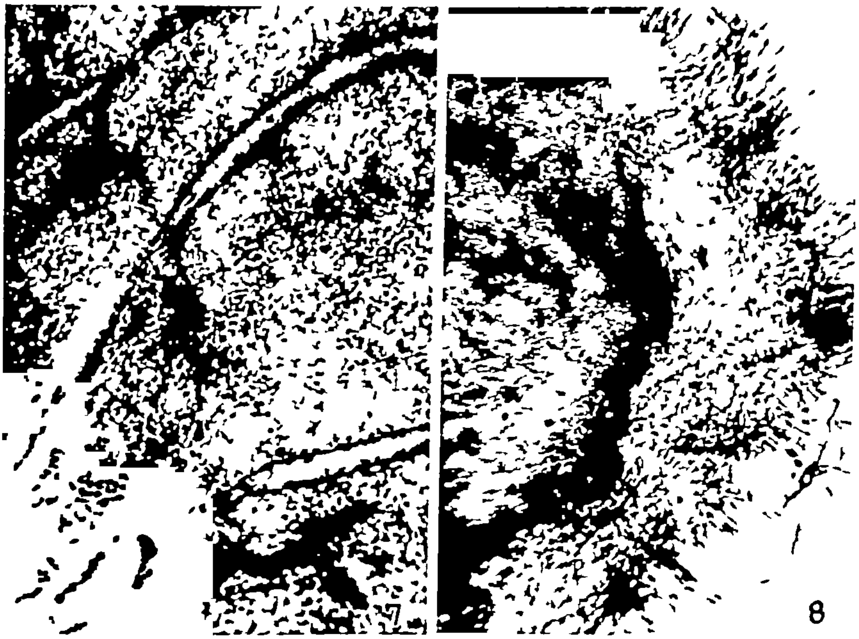
Fetal Tissue.—The factors involved in the differentiation of the respiratory tree, including the forces which ultimately arrest its successive branchings and the determination of the final form of its epithelium including the vexatious question of the character of the alveolar wall are among the many unsolved problems of pulmonary histogenesis. Tissue cultures of human fetal lung provide very attractive objects of experimental analyses of these questions. After three days of incubation an explant of lung from a three month human fetus (Fig. 1) revealed the pattern of saccular terminal buds. While the epithelial components of the system remained in position, connective tissue elements showed rapid peripheral emigration as spindle and phagocytic wandering cells (Fig. 2). Mitotic figures were frequent (Figs. 3 and 4). The cut ends of bronchioles often appeared to have become sealed primarily as a result of epithelial activity. Similarly, buds isolated in the cutting of explants rapidly became closed systems in fields of mesenchymatous elements (Fig. 2), a propensity possibly involved in mucoviscidosis.

While engaged in experiments designed with other goals in mind, a series of lung cultures was allowed to develop at both room and incubator temperatures. After thirty days at 37° C. the epithelium was represented only by pyknotic nuclei in terminal sacs while the pattern of the bronchi was clearly defined by spindle cells (Fig. 5). In contrast cultures maintained for forty-five days at 27° C. retained a conspicuous epithelial system but with a marked tendency for the isolation of cystic bodies (Fig. 6). Experiments paralleling these observations were performed with explants of the testes of newborn rats. Residence for twenty-four days at 37° C. produced cultures in which the seminiferous tubules were of very small diameter and generally widely separated by cells believed to be connective tissue derivatives (Fig. 7). Corresponding cultures exposed to 27° C. for the same period of time not only showed reduction of spindle elements, but the coalescing of the epithelium from the tubules to form a continuous plate of cells. Evidence of the contributions of individual seminiferous tubules was indicated by the scalloped margin of the epithelial sheet (Fig. 8). Consultation of the cross-indexed bibliography of the research in tissue culture by Murray and Kopech[13] reveals several important references dealing with the effect of temperatures, hydrogen ion concentration, and other variables on the differential growth of epithelial versus connective tissue elements. Fruitful inroads might be made



Figs. 1, 2, 3 and 4. The appearance of a typical culture of lung tissue from a 3 month [illegible] after three days of incubation. Stained with Delafield's hematoxylin. [illegible] with terminal buds. Note the emigration of mesenchymal [illegible] Fig. 1 [illegible] epithelial bud which has become sealed to form a cystic [illegible] elements. Fig. 3 The epithelium of a [illegible] figure. Fig. 4 Small elements in the outgrowth





Figs. 5 and 6.—Sister cultures of lung from a 3 month old human fetus stained with Delafield's hematoxylin. Fig. 5, Appearance of a culture after incubation at 37° C. for thirty days. Note the destruction of the epithelial components and the persistence of the bronchiolar framework of connective tissue elements. Fig. 6, Culture maintained at 27° C. for forty-five days showing the persistence of epithelial elements. Note the frequency of isolated cystl masses.

Figs. 7 and 8.—Sister cultures of the testis of a newborn rat in vitro for twenty-four days. This experiment was used to extend the observation made on lung tissue regarding the effect of temperature on the persistence of epithelium in vitro. Both preparations were stained with Delafield's hematoxylin. Fig. 7, Relative increase in cells of connective tissue origin at the expense of the seminiferous epithelium in cultures maintained at 37° C. Fig. 8, Confluence of epithelium in the form of a plate with a scalloped margin suggesting the contribution of individual seminiferous tubules and a corresponding decrease in spindle cell from a culture maintained at 27° C.

toward explaining congenital abnormalities of the respiratory system with the use of human fetal lung material cultivated under the highly controllable conditions afforded by available methods.

Surgical Specimens.—It is obvious that tissue specimens obtained in the course of the surgical activities of an average-sized hospital can provide an enormous amount of material for culture. Tonsillar tissue discarded from one child can be used in the preparation of several hundred explants. In addition to the study of the pathologic process per se, a given specimen usually can provide a large amount of relatively normal tissue. Thus a useful deposit of cultures can be prepared as a by-product of pneumonectomies which can be used for basic studies including experimental infections and the induction of neoplasms.

Of special interest is the opportunity of cultivating tissues obtained by bronchoscopic biopsies. Fig. 9 shows a four-day outgrowth of epithelial cells from the bronchial lining of the right lower lobe of a 72-year-old white man (WmBe—JSH 6639.1) with a diagnosis of intrinsic bronchial asthma and compensatory emphysema who had had a rectal resection for papillary adenocarcinoma two years earlier. The appearance of the nucleoli (*N*), nuclear membrane (*M*), mitochondria (*Mt*) and of fatty droplets (*F*) in living cells photographed with phase microscopy are shown in Fig. 10. Two mitochondrial patterns as revealed with the silver carbonate method are represented in Figs. 11 and 12.* While final results from this study are not yet available, the illustrations are presented as suggestions of the type of study objects not generally available for clinicopathologic study which might prove of special merit.

Cultures of Biopsies From the Nasal Mucosa.—This topic deserves special treatment since it forms a very important area of investigation in our research program and because the essential findings obtained thus far may be applicable to areas deeper within the respiratory tree.

Both simple hanging-drop and roller-tube techniques have been used for the development of short-term epithelial cultures of unanesthetized biopsy material. Specimens derived from the posterior portion of the middle turbinate provide outgrowths of cells which show ciliary motion for approximately two weeks. Suggestions regarding the opportunities afforded by such preparations for the study of allergy have been outlined by Pomerat.[10, 11] While specimens can be readily obtained from subjects with well-studied clinical manifestations of hypersensitiveness and while the use of perfusion chamber technique in combination with phase cinematography is well established, it has not been considered wise to make detailed explorations on the effect of histamine, antihistamines, antigens and immune bodies until a considerable body of information on the biology of the human nasal mucosa has been accumulated. Accordingly, several thousand feet of 16 mm. film records have been prepared which illustrate membrane behavior including pinocytosis (cell drinking), nuclear activity and the mobility of the mitochondria. In the course of these observations nuclei were seen to exhibit rotatory activity.

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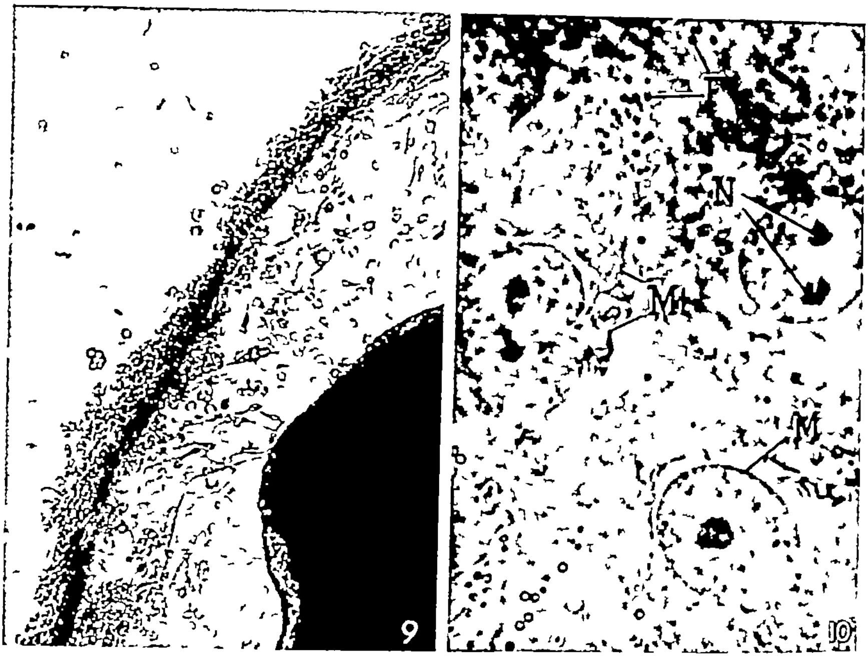
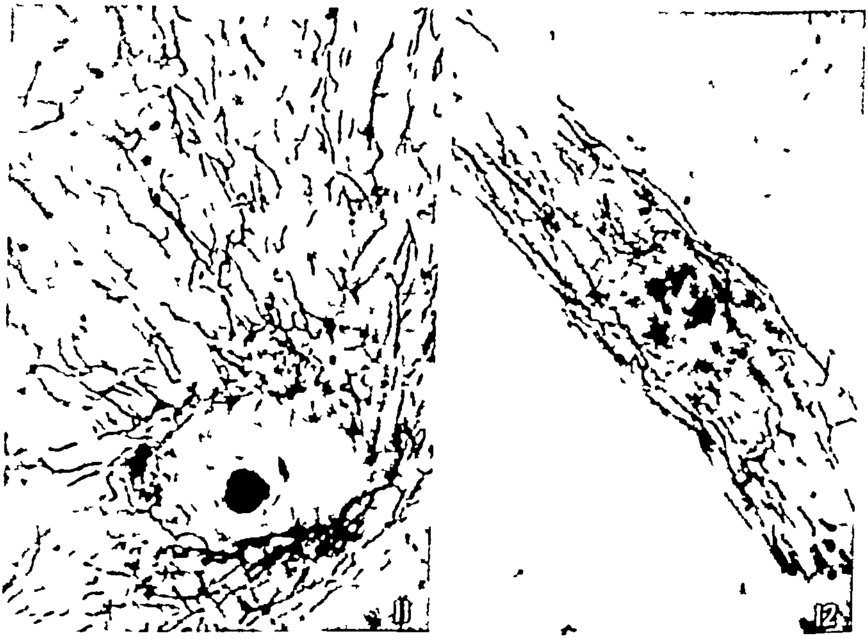
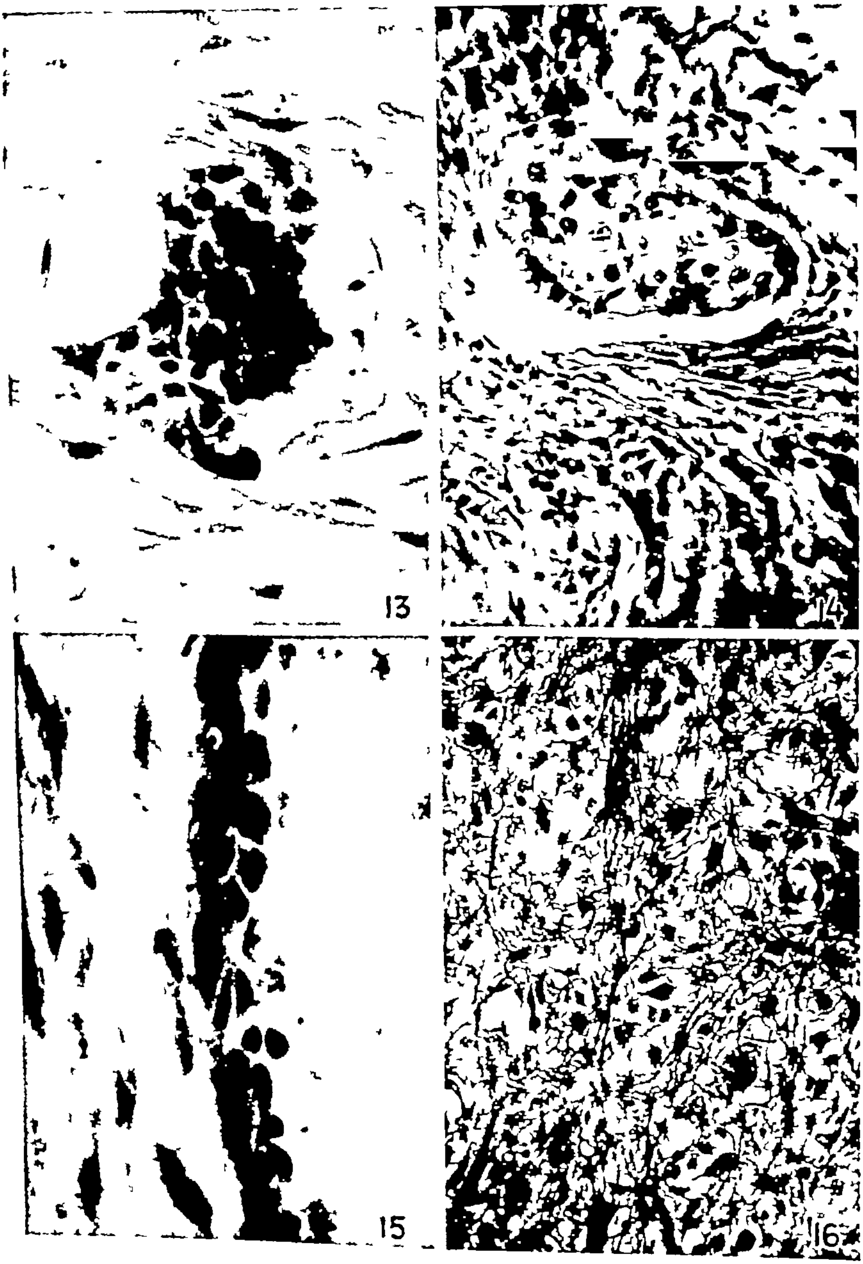
* [illegible] Dr. Patrick M[illegible] for his cooperation in obtaining [illegible] preparation.





Figs. 9 and 10.—Cells from cultures of bronchial lining from a biopsy of the right lower lobe. The patient, a 72-year-old white man (WmBe—JSH 6639 I) with a diagnosis of intrinsic bronchial asthma and compensatory emphysema, had a rectal resection for papillary adenocarcinoma two years earlier. Fig. 9, Outgrowth from a 4-day-old living hanging-drop culture showing a zone of emigrating epithelial cells. Ordinary light microscopy at low power. Fig. 10, A group of cells from the epithelial sheet shown in Fig. 9. Note the nucleoli (*N*), nuclear membrane (*M*), mitochondria (*Mt*), and fatty droplets (*F*). Oil immersion dark phase contrast microscopy.

Figs. 11 and 12.—Mitochondria showing a diffuse pattern (Fig. 11) and perinuclear aggregation (Fig. 12) as revealed in a nine-day culture stained according to Polak's silver method.



Figs. 13, 14, [illegible] and 16.—[illegible] micrographs from a study of a [illegible]-year-old white man [illegible] with a [illegible] accumulation of pleural fluid. [illegible] in the [illegible] which was stained with hematoxylin and eosin. Jacobson's [illegible] epithelial plate and surrounded with stromal elements [illegible] in vitro after twelve days of incubation [illegible] is compared with a characteristic [illegible] in the pericardium (Fig. 14). Fig. [illegible] Zone of contact between [illegible] day cell culture. Careful examination revealed [illegible] of squamous cell epithelioma, probably [illegible]

Fig. [illegible] fibers from a 31 day [illegible] culture of cells in the chest [illegible] who [illegible] an active pleural [illegible]

In one sequence a nucleus was found which completed sixteen revolutions within seventy-five minutes, at one point the nucleus having turned through 360 degrees in seventy seconds[15] Subsequently, nuclear rotation was observed in epithelia from other organs grown in vitro Studies in progress are designed to clarify the mechanism involved and its meaning in the economy of the cell

Current work also has demonstrated reactions in cell form and activity following experimental changes in electrolyte balance Evidence is being accumulated which supports the view that 0 9 per cent sodium chloride in water is markedly nonphysiologic and that balanced salt solutions especially those containing colloidal substances such as various plasma substitutes might be used with far better results for washing delicate epithelial membranes

Exfoliated Cells in Bronchial Secretions and Pleural Fluid—Cell cultures are ideal for the study of free cells which are shed from various body surfaces It was pointed out by Cone, Hooks Pomerat, and Rose[16] that correlation studies might well be conducted between histopathologic, Papanicolaou and tissue culture techniques in the analysis of the cytology of diseases affecting the urogenital tract A broader statement of the problem was made by Pomerat Nowinski, and Rose[17] and the application of the method to breast secretions was reported by Pomerat[18] and by McCormick, Jackson and Pomerat [19]

It would seem that the cultivation of cells in bronchial secretions and lavages from particular areas of the pulmonary tree might prove especially valuable for studies in chest pathology

Several authors notably Hengstmann [20] Coman,[21] and Sano and Bello have given evidence of the value of tissue cultures of pleural fluid in the diagnosis of pulmonary disease In our own series* several very interesting diagnostic enigmas have been unraveled For example, the pleural fluid cultivated from a 62-year-old white man (W A Wh-JSH 11315 F) produced a "lesion" on glass (Fig 13) strikingly similar to that found post mortem (Fig 14) A careful study of epithelial boundaries in the tissue culture revealed intercellular bridges (Fig 15) an observation which lent weight to a final diagnosis of squamous cell epithelioma having probably originated from bronchial epithelium

For in vitro studies, the rapid development of reticular fiber feltworks directly on the cover glass of cell cultures from pleural fluids lends itself favorably for experimental studies upon acellular fibrillar formation Fig 16 illustrates such a system in a 31-year-old culture of pleural sediment from a 53 year old white man (PeIIo—St MI#5245-51) who showed an active pleural reaction

It is hoped that a comprehensive analysis of an adequate series of the type provided by these illustrations may help in establishing a wider use of this very promising application of the tissue culture method in the study of chest diseases

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*Work in progress in collaboration with Dr I J Lefeber and Dr C C Rose

Grateful acknowledgment is made to Dr A P Stout for his kindness in studying our preparations of tissue cultures

SUMMARY

Methods are described for the study of pulmonary tissue and cells in pleural fluid with tissue culture technique

Explants of human fetal tissues suggest attractive tools for the analysis of histogenesis and the development of congenital anomalies

Surgical specimens and especially biopsies of the nasal mucosa and bronchial lining provide explants which become readily established in vitro and which invite challenging studies on the dynamics of cell activity The analysis of nuclear rotation as seen in outgrowths from the nasal mucosa exemplifies newer knowledge emerging from the study of "living histology"

Data provided by the cultivation of cells from pleural fluid suggest the importance of adding such information to that obtained by well-established pathologic procedures as aids in understanding the nature of disease processes It follows that the culture of cells from bronchial secretions may afford promising new diagnostic opportunities

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22 [illegible] The Value of Differentiating Between [illegible] Tissue Culture [illegible] Surg 81 [illegible] 1951

CARCINOMA OF THE LUNG

A Report of 403 Cases

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INTRODUCTION

THE increasing incidence of cancer of the lung has been amply documented in the recent literature. Thus, reviews by Graham[1] Ochsner,[3] and others suggested that there has been an almost alarming increase in the number of diagnosed cases. This increase may be entirely absolute or partially relative. Inasmuch as carcinoma of the lung is the commonest cancer in males in many large institutions, it behooves all of us to examine our records and determine if possible what can be done to improve our results.

This report is based on a study of 403 patients with carcinoma of the lung seen at the Lahey Clinic during the past fifteen years. There were 350 males and 53 females, a ratio of 6.6 to 1, although, as will be indicated subsequently, this ratio does not hold for all types of bronchogenic carcinoma (Table I).

We were concerned especially in assessing our results in terms of five year survivals; therefore we divided the patients into those 159 seen before Jan. 1, 1948, and those 224 seen in the period from January, 1948, to December, 1952 (Table I).

TABLE I. SEX DISTRIBUTION

Males	350
Females	53
Ratio—6.6 Males to 1 Female	
	Cases
Before 1948	159
1948 to 1952	244

Of great interest today is the question of cigarette smoking in relation to cancer of the lung. There is certainly some suggestive evidence of a causal relationship but despite the enthusiastic endorsement of this etiological factor by eminent thoracic specialists it would appear that a longer period of time will be required to settle this still controversial point (Table II).

Read at the Thirty-fourth Annual Meeting of The American Association for Thoracic Surgery at Montreal, Quebec, May 3 to 5, 1954.

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TABLE IV SYMPTOMS (403 CASES)

SYMPTOMS		PATIENTS	PER CENT
Cough		333	82.6
Productive	283		
Nonproductive	50		
Weight loss		276	68.4
Chest pain		231	57.3
Dyspnea		201	49.8
Hemoptysis		190	47.1
Weakness, fatigue		170	42.1
Wheeze		65	16.1
Other		280	69.4

TABLE V CHIEF SYMPTOM (403 CASES)

SYMPTOM		PATIENTS	PER CENT
Cough		167	41.4
Productive	145		
Nonproductive	22		
Chest pain		142	35.2
Hemoptysis		72	17.8
Weight loss		57	14.1
Dyspnea		51	12.6
Wheeze		5	1.2
Other		115	28.5

TABLE VI DURATION OF CHIEF SYMPTOMS BEFORE COMING TO CLINIC

DURATION (MONTHS)	PATIENTS	PER CENT
0 to 3	206	51
3 to 6	158	39
6 to 9	116	29
9 to 12	23	6
Over 12	112	28

On completion of the history and physical examination the diagnosis of cancer of the lung was made in 260 cases or 64.5 per cent of the total. Furthermore, metastases were indicated clinically in 105 or 26 per cent. The location of these metastases is included in Table VII. It will be noted that clubbing of the fingers was found in only 7 per cent of the cases and paralysis of the recurrent laryngeal nerve in 4.7 per cent.

TABLE VII PHYSICAL EXAMINATION (403 CASES)

Tumor of lung diagnosed—260 cases or 64.5%	
Metastases—105 cases* or 26.0%	
Cervical	26
Bone	26
Axillary	10
Pleura	13
Liver	11
Spinal cord	10
Brain	4
Chest wall	3
Mediastinum	5
Pancreas	1
Involvement of recurrent nerve—19 cases or 4.7%	
Clubbing—29 cases or 7.1%	

*Two patients had metastases in two sites

SPECIAL STUDIES

Roentgen Studies.—The roentgenogram is the most consistently accurate diagnostic tool at our disposal. The diagnosis was indicated by the radiologist in 364 of the 403 cases or about 90 per cent (Table VIII). Many of these cases, however, were far advanced. New techniques in roentgen diagnosis are urgently required to permit earlier diagnosis of intrabronchial lesions. The use of high-voltage radiography is an encouraging step in this direction.

TABLE VIII. RESULTS OF DIAGNOSTIC PROCEDURES

	PATIENTS	PER CENT
Bronchoscopy	312	77.4 of 403 patients
Clinically positive	193	61.8 of 312 patients
Biopsy	184	
Positive	132	42.3 of 312 patients
Papanicolaou smear	117	
Positive	59	50.4 of 117 patients
X-ray positive	364	90.3 of 403 patients

Bronchoscopy and Cytology.—Bronchoscopy does not give the high percentages of positive results indicated by the earlier observers. In our hands, a positive diagnosis was made by this method in 42.3 per cent of patients who were submitted to the examination (Table VIII). There was one instance of false positive smear in the entire series but cytological study was positive in 50 per cent of the proved cases in which it was employed.

TABLE IX. LOCATION (403 CASES)

	CASES	PER CENT
Left		
Upper lobe	61	15
Lower lobe	35	8.7
Main stem bronchus	13	3.2
Both lobes	2	0.5
Hilum	51	12.6
Total	162	40
Right		
Upper lobe	92	23
Middle lobe	11	3
Lower lobe	40	10
Main stem bronchus	18	4.5
Middle and lower lobes	8	2
Upper and middle lobes	2	0.5
Hilum	50	12
Total	221	55
Carina	7	2
Undetermined	13	3

Incidence.—There were 217 patients or 53.8 per cent of the total subjected to exploration and thus given a chance for surgical relief. This will be discussed later.

PATHOLOGY

The gross pathology of primary carcinoma of the lung is epitomized in a chart in Fig. 1. Unfortunately the pathologic entities shown on the right side of the drawing are still frequently encountered The huge cancerous deposits around the carina, often with a relatively small, bronchogenic primary lesion, are doubtless tumors once called sarcoma of the mediastinum.

Of the patients considered here, 221 had carcinoma of the right lung and 162 of the left, while 7 so involved the carina and lower trachea that the exact origin was in doubt (Table IX)

The microscopic pathology has been reported to us by Dr Shields Warren and Dr William A Meissner of the New England Deaconess Hospital Department of Pathology as follows (1) epidermoid carcinoma 136 cases (2) undifferentiated carcinoma, 90 cases, (3) adenocarcinoma, 43 cases (4) carcinoma simplex, 30 cases, and (5) alveolar carcinoma, 2 cases (Table X)

TABLE X. PATHOLOGY (403 CASES)

	CASES
Epidermoid carcinoma	136
Undifferentiated carcinoma	90
Adenocarcinoma	43
Carcinoma simplex	30
Alveolar carcinoma	2
Total	301
Positive Papanicolaou smear only	27
Total positive diagnoses	328
No pathology	75
	403

Epidermoid Carcinoma—This is the typical carcinoma of the bronchus in the male, and is often associated with atelectasis, necrotic cavitation or abscess It develops in the cuboidal or columnar normal epithelium of the endobronchus by a process of metaplasia and neoplasia Thus it is the lesion that could be the result of chronic bronchial irritation, such as might be caused by tobacco

Undifferentiated Carcinoma—As the name suggests, this neoplasm is so immature that it is not possible to determine the cell type of origin This is variously described as anaplastic carcinoma, reserve cell carcinoma and oat cell carcinoma

Adenocarcinoma—This is the lesion usually called adenocarcinoma Grade 2 by those who use Broders' scale Of 43 patients in whom this diagnosis was returned 13 (approximately 1 out of 3) were women It will be recalled that for the total series of carcinoma of the lung, the ratio of females to males was 1 to 6 6 Furthermore 13 of the 43 stated that they did not smoke and 3 others probably did not

The etiology of this type of carcinoma may be entirely different from that of the more common epidermoid cancer Pre existing congenital rests and benign tumors at times have been suggested Here again however the evidence is far from conclusive On this confession of ignorance our present conception of the pathogenesis of carcinoma of the lung must temporarily rest right side of the drawing are still frequently encountered. The huge cancerous deposits around the carina, often with a relatively small, bronchogenic primary lesion, are doubtless tumors once called sarcoma of the mediastinum.

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Carcinoma Simplex.—This is the lesion that at times is called adenocarcinoma Grade 3 or 4. Occasionally islands of very poorly formed glands may be found but the majority of the tumor is composed of solid sheets of undifferentiated cells.

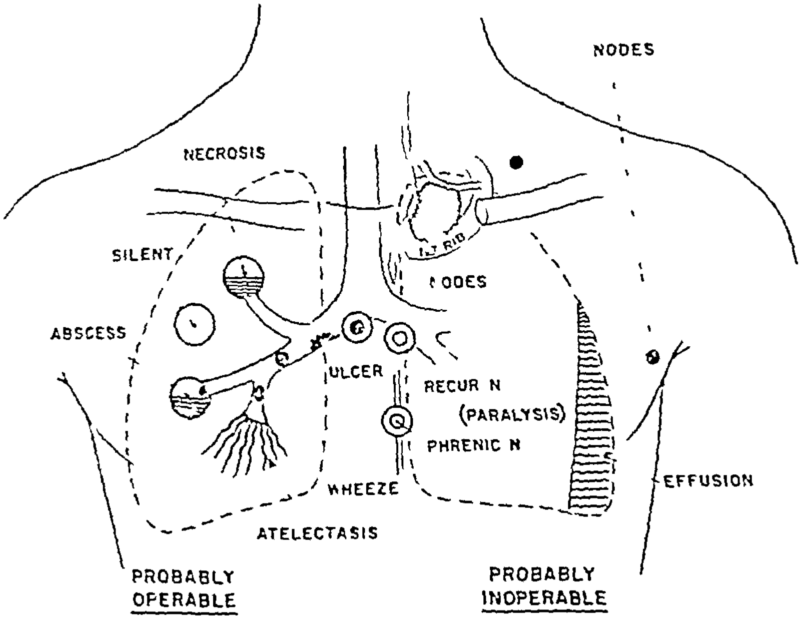


Fig. 1.—The gross pathology of carcinoma of the lung is shown diagrammatically. The erosion of the rib should be posterior. The liver should be carefully palpated and the pleural [illegible] searched for tumor cells.

Alveolar Cell Carcinoma.—This is a rare lesion about which there has been considerable speculation in recent years. It has been compared to a South African sheep disease and from the standpoint of pathogenesis it is believed to have a multicentric origin. It may well be simply a variant of one of the other types. There were two recognized examples of this lesion in 403 cases.

TREATMENT

The Question of Lobectomy.—Despite the strongly expressed sentiments in the literature regarding lobectomy and realization of its inadequacy, there still will be many cases in a large experience in which lobectomy is mandatory (Table XIV). Thus a close inspection of the other lung may reveal roentgenographic changes suggestive of silicosis, fibrosis of other kinds, cystic disease, old infection or emphysema. A low total pulmonary function or poor selective function on the contralateral side may indicate clearly the serious hazard of pneumonectomy. Although details of technique (Figs. 2 to 5) cannot be [illegible] into here, it is to be emphasized that a very radical lobectomy may be done at times. This is especially so if the upper lobe is involved, as it is [illegible] frequently. Thus, with the pericardium opened and provisional control of the main pulmonary artery established the upper lobe artery may actually be cut away from the trunk artery and the defect carefully oversewn with two layers of silk The first layer is a mattress of fine interrupted silk after

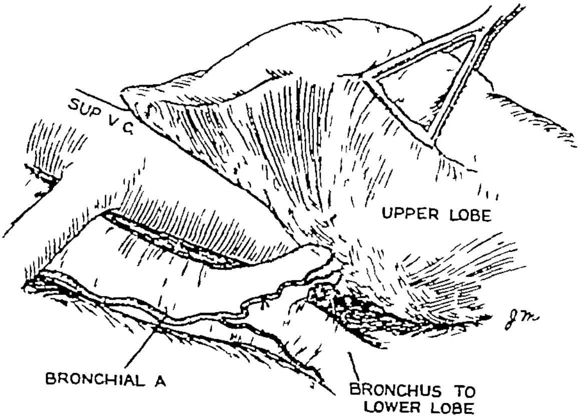


Fig 2 —This and the succeeding three drawings illustrate the technique of radical lobectomy that is sometimes possible The upper lobe is lifted forward and the azygos vein divided The trachea and bronchi are wiped down and the bronchial arteries ligated high Lymph nodes at the lobar bifurcation may be included in the specimen (From Surgical Practice of the Lahey Clinic 1951 courtesy W B Saunders Company)

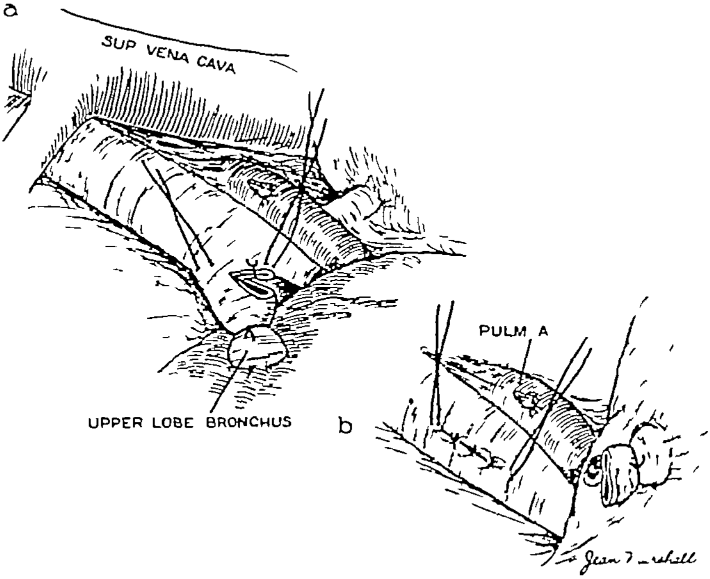


Fig 3 —*a* and *b* The lobe is then turned back the lobar artery secured high and the bronchus amputated (Courtesy W B Saunders Company)

which the everted cuff is oversewn by a continuous suture of fine silk This is very similar to our previously described manner of anastomosing the aorta after resection Then the azygos vein may be divided and the trachea wiped clean down to and around the main bronchus

TABLE XI. ANALYSIS OF 104 RESECTED CASES

	CASES	PER CENT
Total pneumonectomy	72	69.2
Right pneumonectomy	37	35.5
Left pneumonectomy	35	33.6
Lobectomy	32	30.7

Of 104 resected cases 32, or 30.7 per cent, were lobectomies. It will be seen later that several of these patients are included among the long term survivals.

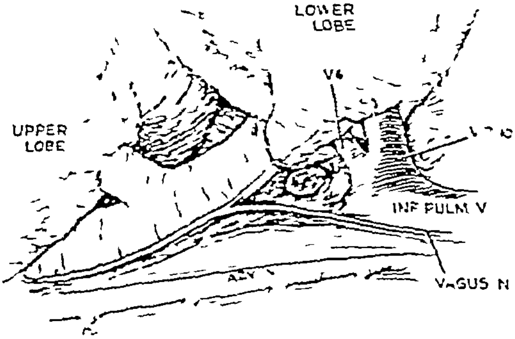
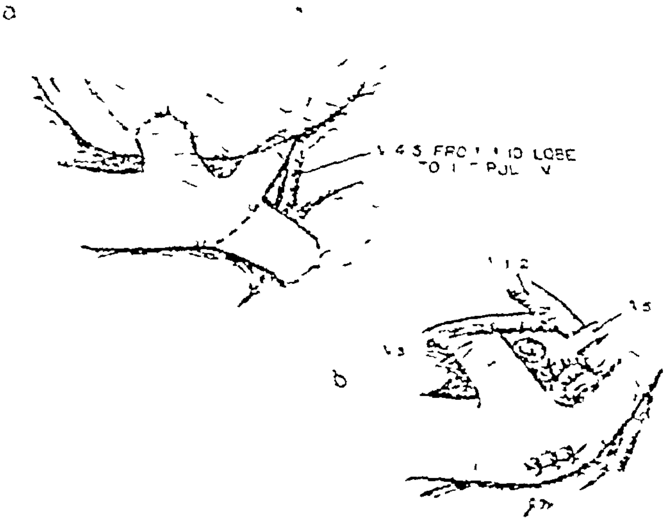


Fig. 4. The hilar dissection is begun posteriorly in a radical lower lobectomy. (Courtesy W. B. Saunders Company.)



[illegible] W. B. Saunders Company [illegible]

Radical Pneumonectomy and High Voltage Therapy.—The ideal treatment [illegible] is radical pneumonectomy as described recently by us and by [illegible] the availability of [illegible] million volt therapy at Massachusetts [illegible] a number of cases have been seen in which radical surgery has been combined with massive radiotherapy A preliminary report on this new approach to therapy has been presented elsewhere In brief it consists of attempting to make inoperable lesions resectable by interposing surgery midway along the course of radiation therapy (Fig 6) We have not

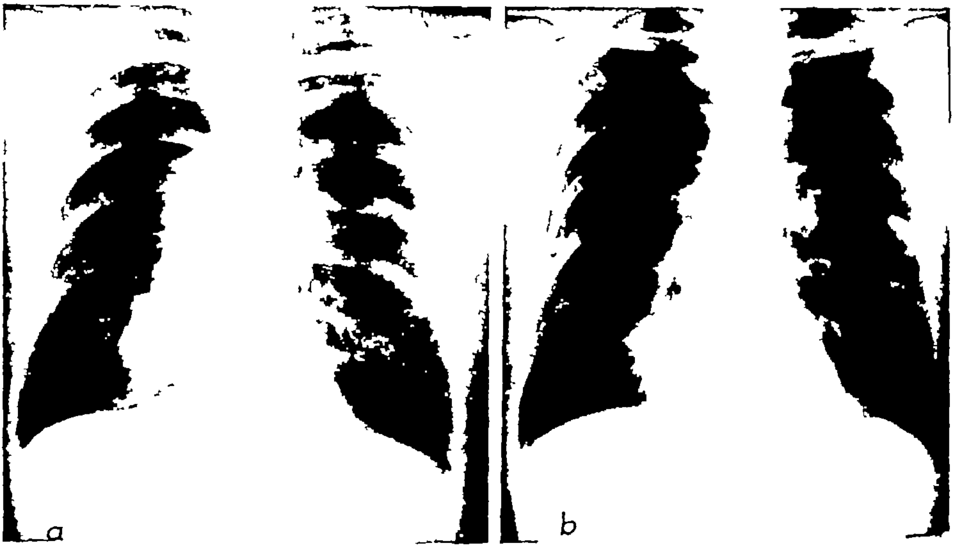


Fig 6 —a Large carcinoma of right lung found inoperable at bronchoscopy b After 3 500 r of high voltage therapy directed to the right hilum and superior mediastinum Improvement in the roentgenogram is apparent.

been impressed with our preliminary experience with this method although it does make certain lesions resectable Furthermore we are persisting with the high voltage therapy of certain squamous cell carcinomas of the lung because we are sure they are sensitive to this type of therapy In general it can be said however that the x-ray is not a substitute for surgery because it destroys the lung and usually causes chronic abscesses and intractable cough More recently we have given the total dosage of high-voltage therapy to these patients before operation A total of 6,000 roentgens may be given without damaging the skin In view of the destruction caused by this intensive therapy pneumonectomy must be planned in addition It has seemed wise to wait one or two months after cessation of therapy before operating on these patients This permits the acute radiation reaction to subside

Radical operation is accomplished with considerable difficulty in these cases It is of great interest however to note that although neoplastic cells may be found in the specimen they are necrotic and nonviable (Fig 7)

Our experience with this entire aspect of therapy of carcinoma of the lung will be reported fully in the future

Tables XII to XX give a résumé of our experience with high voltage therapy in a total of 97 patients The condition of the patients and the effects of treatment are such that only 61 of 97 completed the course It will be observed that 76 per cent of those who completed therapy are now dead. This small series could be materially improved statistically if 3 unusual cases were included as good results (Table XV). We have chosen not to do so, however, since they were relatively long-term surgical cures. Thus they are exceptions to the usual inherently vicious nature of the disease.

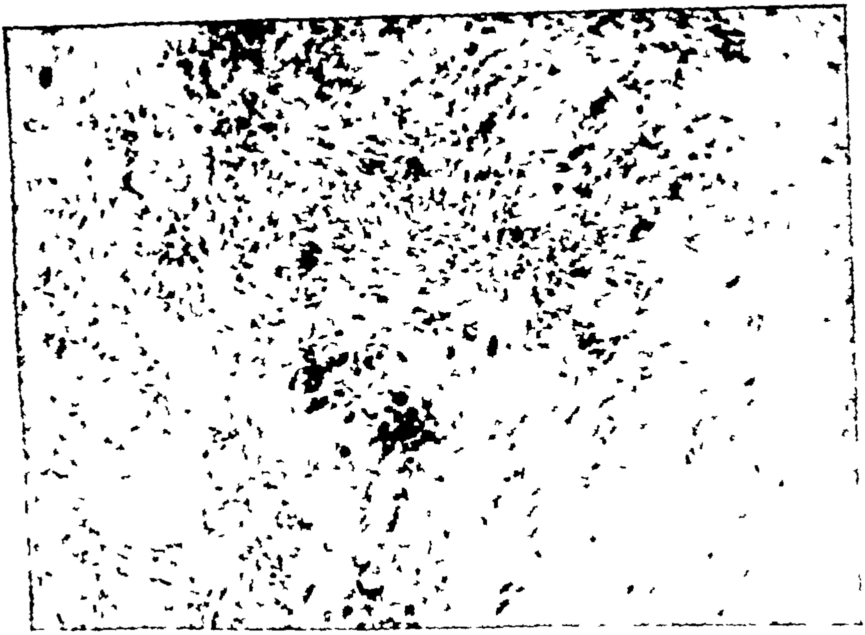


Fig. 7.—Specimen removed at pneumonectomy after high voltage therapy. Note that [illegible] nt, but are necrotic and nonviable. Several scores of fields were [illegible] tumor cells were found.

Our over-all experience in the therapy of carcinoma of the lung in 403 cases is summarized in Table XXI. It will be seen that resection was performed in 104 of 403 cases, a percentage of 25.8, while medical treatment only was advised on clinical examination for 186 patients, or 46 per cent. Surgery was refused by 11 patients, or 2.7 per cent of the group. It is of special interest to us to note that surgery appeared contraindicated for medical reasons in only 4 patients, less than 1 per cent of the group.

Resectability.—The accepted criteria of inoperability in the past have been extension to or fixation of the carina, obvious distant metastases, and pleural fluid positive for tumor cells. We have made a special point of searching diligently in all cases for enlarged lymph nodes in the neck and the axilla, and in a number of cases we have succeeded in finding removable nodes for biopsy and thereby established the hopeless nature of the disease. On the other hand, as indicated and as reported previously, we have managed [illegible] cases to shrink down epidermoid carcinomas of the lung using high voltage [illegible] therapy so that the carina was no longer involved. Needless

Table XII Cases Considered Inoperable at Exploration, Treatment With High Voltage X Rays Only

			TIME INTERVAL (MONTHS) FROM			
CASE	MIT NO	PROVED PATHOLOGY	DIAGNOSIS TO TREATMENT	TREATMENT TO LAST FOLLOW UP	DIAGNOSIS TO LAST FOLLOW UP	COMMENT
1	50 001	No	0	5 D*	5 D	General metastatic disease
2	50 049	Yes	½	4 D	4½ D	Diffuse lung metastases
3	50 060	Yes	½	9 D	9½ D	Recurrence in both lungs
4	51 023	Yes	1	10 D	11 D	Hemorrhage
5	51 071	Yes	½	22½ D	23 D	Spine, visceral metastases
6	51 087	Yes	0	2 D	2 D	
7	51 089	No	14½	16½ D	31 D	
8	51 092	No	0	7 D	7 D	
9	51 095	No	0	8½ D	8½ D	
10	51 107	Yes	0	5 D	5 D	Died after lobectomy for abscess following x ray
11	52 091	No	0	16½	16½	No evidence of disease
12	52 271	Yes	0	3 D	3 D	
13	52 293	No	0	9½ D	9½ D	Distant metastases
14	52 314	No	0	9	9	Alive metastases to liver and intestine
15	53 274	Yes	0	2½ D	2½ D	Multiple metastases
16	53 157	Yes	½	8	8½	Coughing, occasional hemoptysis
17	53 013	Yes	1	12½ D	13½ D	Metastases
18	53 260	Yes	0	3 D	3 D	
19	53 335	Yes	½	2 D	2½ D	Metastases to liver
20	53 241	Yes	0	5 D	5 D	Metastases to liver
21	53 283	Yes	½	5 D	5½ D	
22	53 276	Yes	1½	4½	6	Pneumonectomy for necrotic lung following x ray
	Average		0 9	7 8	8 7	
	Range		0 14½	2 22½	2 31	
	Proved pathologically			15		
	Not proved			7		

Of 22 patients 18 dead (average survival after diagnosis—8 1 months) 4 alive (average survival after diagnosis—10 0 months)

*D = Dead

Table XIII Cases Considered Inoperable at Exploration, Treatment With High Voltage X Rays Only (Carcinoma Proved Pathologically)

		TIME INTERVAL (MONTHS) FROM			
CASE	MIT NO	DIAGNOSIS TO TREATMENT	TREATMENT TO LAST FOLLOW UP	DIAGNOSIS TO LAST FOLLOW UP	COMMENT
1	50 127	3½	3 D*	6½ D	Metastases to brain
2	51 117	1½	15 D	16½ D	
3	51 119	1½	12 D	13½ D	Cardiac failure
4	51 135	1½	9 D	10½ D	Cardiac failure
5	52 044	1	11½ D	12½ D	Metastases to thyroid opposite lung
6	52 146	1	15 D	16 D	Hemoptysis ruptured aorta(?)
7	52 156	½	16	16½	*Alive but terminal*
8	53 047	1½	6½ D	8 D	Metastases to ilium
9	53 230	½	4½ D	5 D	Metastases to brain primary thyroid(?)
10	53 041	1	9½	10½	Alive with brain metastases
11	53 195	1½	7½ D	9 D	Massive hemoptysis
12	53 327	1	4	5	Fair except for pneumonitis
	Average	1 3	9 4	10 8	
	Range	½ 3½	3 16	5 16½	

Of 12 cases 9 dead (average survival after diagnosis—10 8 months) 3 alive (average survival after diagnosis—10 6 months)

*D = Dead

to say this will be of no avail if distant metastases develop as may occur, but we have found no residual tumor in the chest of a patient with advanced disease who died of a distant metastasis

TABLE XIX ALL CASES NOT RESECTED TREATMENT WITH HIGH VOLTAGE THERAPY ONLY

		CASES	AVERAGE SURVIVAL (MONTHS)
Not resected		34	9.4
Unexplorable	22		
Explored—inoperable	12		
Alive		7	10.3
Dead		27	9.2

TABLE XX THREE SPECIAL CASES TREATED SURGICALLY, RECURRENCE FROM 3 TO 9 YEARS LATER TREATED WITH HIGH VOLTAGE THERAPY ALL 3 PROVED PATHOLOGICALLY

		TIME INTERVAL FROM			
CASE	HOSP. NO.	OPERATION TO X-RAY TREATMENT	X-RAY TREATMENT TO LAST FOLLOW UP	DIAGNOSIS TO LAST FOLLOW UP	COMMENT
1	[illegible]	3 years	9½ months	3 years 9½ months	Metastasis to brain terminal
2	[illegible]	6 years 11 months	17 months	8 years 4 months	Cough and fever excision of necrotic lung (?)
3	50 110	9 years 11 months	32 months	12½ years	Persistent cough no adenopathy

Of the total cases of carcinoma of the lung 25.8 per cent of the patients were submitted to resection (Table XXII) The total resections were almost equally divided between right and left total pneumonectomy The future should witness a larger percentage of resectable cases

TABLE XXI TREATMENT SURGERY (LOBECTOMY) PLUS HIGH VOLTAGE THERAPY (CARCINOMA PROVED PATHOLOGICALLY)

			TIME INTERVAL (MONTHS) FROM			
CASE	HOSP. NO.	[illegible]	OPERATION TO X-RAY TREATMENT	X-RAY TREATMENT TO LAST FOLLOW UP	DIAGNOSIS TO LAST FOLLOW UP	COMMENT
1	[illegible]	0	14	17 D	31 D	Metastases to opposite lung
2	[illegible]	0	13	13 D	[illegible] D	Metastases to brain
[illegible]	[illegible]	0	[illegible]	2½ D	[illegible] D	
4	[illegible]	0	[illegible]	4 D	[illegible] D	
[illegible]	[illegible]	0	13	[illegible] D	17 D	Metastases to brain
Average			10.4	14		
Range		[illegible]	[illegible] 17	[illegible]		

[illegible] [illegible] months

MORBIDITY AND MORTALITY

Postoperative complications have been largely in the pneumonectomy group In Table XXIII it will be noted that there were 17 deaths in the [illegible] group Eight patients died in hospital following pneumonectomy a

TABLE XVII TREATMENT SURGERY (PNEUMONECTOMY) PLUS HIGH VOLTAGE THERAPY (CARCINOMA PROVED PATHOLOGICALLY)

		TIME INTERVAL (MONTHS) FROM				
CASE	MIT NO	DIAGNOSIS	OPERATION TO X RAY TREATMENT	X RAY TREATMENT TO LAST FOLLOW UP	DIAGNOSIS TO LAST FOLLOW UP	COMMENT
1	51 039	0	2½	24 D*	26½D	
2	51 070	0	½	12 D	12½D	Metastases to adrenals, kidney, no residual tumor in lung
3	51 161	½	1½	17	19	
4	52 089	2	—	9 D	11 D	Metastases to brain, operation midway through x ray treatment
5	52 186	1	—	6 D	7 D	Operation midway through x ray treatment
6	53 277	0	1	3	4	Feels well
7	53 163	0	½	3½	4	Feels weak
8	53 246	0	1	6	7	Metastases to bones
9	53 213	0	1	1½	2½	No follow up
10	53 228	0	1	4½D	5½D	Carcinomatosis
11	53 217	0	½	8	8½	Alive but terminal
	Average			8.6	9.7	
	Range			1½ 24	2½ 26	

Of 11 cases 5 dead (average survival 12.5 months) 6 alive (average survival months)

*D = Dead

TABLE XVIII TREATMENT SURGERY AND HIGH VOLTAGE THERAPY (ALL CASES)

		CASES	AVERAGE SURVIVAL (MONTHS)
Total		16	
Lobectomy	5		
Pneumonectomy	11		
Alive		6	7.5
Dead		10	13.2

TABLE XIX TREATMENT WITH CONVENTIONAL X RAY PLUS HIGH VOLTAGE THERAPY

			TIME INTERVAL (MONTHS) FROM				
CASE	MIT NO	PROVED PATH	DIAGNOSIS TO CONVENTIONAL X RAY	CONVENTIONAL TO HIGH VOLTAGE X RAY	HIGH VOLTAGE TO LAST FOLLOW UP	DIAGNOSIS TO LAST FOLLOW UP	COMMENT
1	50 069	No	0	11	22 D*	33 D	Recurrence pneumonitis
2	50 076	Yes	0	6½	30 D	36½D	
3	52 039	Yes	0	13	2½D	15½D	
4	52 094	Yes	0	½	9 D	9½D	Persistent disea
5	52 308	No	0	1½	6½D	8 D	Metastases to both lungs
6	50 143	Yes	0	1	5½D	6½D	Carcinomatosis
7	51 012	No	0	1	26	27	persistent cough
8	51 021	No	1	1	4 D	6 D	
	Average					17.8	
	Range					6½ 36½	

Of 8 cases 7 dead (average survival—16.4 months) 1 alive at 27 months

D = Dead

TABLE XX. SUMMARY OF ALL PATIENTS TREATED WITH HIGH VOLTAGE THERAPY (34), PLUS CONVENTIONAL THERAPY (8), OR PLUS SURGERY (19)

	CASES	PER CENT
Total (average survival 11 months)	58*	
Began high voltage therapy	97	
Completed high voltage therapy	61†	63
Dead—April 1954 (average survival, 11.2 months)	44	76
Diagnosis proved pathologically	50	82
Diagnoses in 50 Cases Proved Pathologically		
Epidermoid carcinoma		
Not graded	3	
Grade 1	2	
Grade 2	7	
Grade 3	6	
Adenocarcinoma	3	
Undifferentiated carcinoma	18	
Alveolar-cell carcinoma	1	
Papillary carcinoma	1	
Papillary adenocarcinoma	1	
Carcinoma not classified	8	
Total	50	
Surgical Treatment in 61 Cases		
Inoperable	42	69
Explorable	31	51
Resectable	19	31

*Three unusual cases of recurrence 3 to 9 years after operation are excluded.
†Including 3 unusual cases (above).

TABLE XXI. SUMMARY OF TREATMENT—403 CASES

TREATMENT	NO.	PER CENT
Medical	186	46.1
Surgical		
Thoracotomy	104	25.8
Palliative	17	4.2
Curative resection	96	23.8
Total	403	

Total surgical operations 217; 53.8 per cent of all patients were given chance for [illegible]

TABLE XXII. RESECTABILITY (403 CASES)

	CASES	PER CENT
Resected	104	25.8 of 403 cases
Curative	96	23.8 of 403 cases or 92.3 of 104 cases
Palliative	8	7.6 of 104 cases

mortality of 7.6 per cent. There was no mortality after lobectomy and there were 9 deaths after exploratory thoracotomy in which the lesion could not be resected, a mortality for thoracotomy alone of 8.6 per cent.

This is a reasonable mortality when it is considered that some of these were in the preantibiotic era and before selective pulmonary function studies were available. This mortality, like the resectability, should be subject to improvement in the future.

TABLE XXIII. MORTALITY

	DEATHS	
	NUMBER	PER CENT
Resected cases		
Pneumonectomy	8	7.6
Lobectomy	0	--
Thoracotomy only	9	8.6
Total mortality	17	7.8 of those operated on

OVER-ALL SURVIVAL

The tragically low salvage in cases of cancer of the lung is well shown by the figures in Table XXIV. The average duration of survival of all patients is 10.7 months after discharge from the hospital or clinic. The average survival of all patients excluding those who lived five years is only 7.9 months. Those patients who were treated medically had an average life duration of only 4.2 months. Patients given x-ray therapy had an average duration of life after leaving the hospital of only 7.9 months.

TABLE XXIV. OVER ALL SURVIVAL

	AVERAGE DURATION OF SURVIVAL (MONTHS)
All patients	10.7
Excluding 5 year cures	7.9
Medical treatment only	4.2
X ray treatment only	7.9
Exploration*	8.9
Exploration only	5.1
Exploration and x ray	12.6
Resection	27.9
Pneumonectomy	23.3
Lobectomy	32.5

*Small group

Patients who had an exploratory operation lived an average of 8.9 months. All those who had resections lived an average of 27.9 months after discharge.

The course of every patient who had a total pneumonectomy was followed. One patient who had a palliative right upper lobectomy in 1946 could not be traced and the few patients seen briefly in consultation who had no surgical procedure at the clinic are not included.

We were able to establish that 15 patients lived five years or more (Table XXV). This percentage is perhaps slightly higher than the usually reported salvage. It is 9.4 per cent of our total cases. To our surprise one patient who had x-ray therapy only is alive after five years. This patient had a thoracotomy and positive biopsy by us and we are indebted to Dr. William Watson of New York for follow-up notes. The patient was seen recently but found to be failing in health from metastasis.

Of the other 14 patients one died of recurrence at five years and one month. Two patients who are alive are believed to have a recurrence, one at

TABLE XXV. FIVE YEAR SURVIVAL

		SURVIVED 5 YEARS OR MORE	
		NUMBER	PER CENT
Of all patients seen		15	9.4
Resection	14		
X-ray only	1		
After resection (palliative resections excluded)			32.5
After curative resection			37.8

five and one half years and one at eleven years. Eleven patients are living and apparently free from disease: 3 patients have survived five years, 3 six years, 2 nine years, 1 ten years, 1 eleven years, and 1 twelve years (Table XXVI).

TABLE XXVI. ANALYSIS OF 15 SURVIVORS

		CASES
Dead of disease in fifth year		2
Believed to have recurrence		2
At 5 year	1	
At 11 years	1	
Still alive		11
5 years	3	
6 years	3	
9 years	2	
10 years	1	
11 years	1	
12 years	1	

It is of interest to consider the pathology in the patients who lived five years inasmuch as the majority of reported five-year cures in the literature are patients who had epidermoid carcinoma (Table XXVII).

TABLE XXVII. PATHOLOGY OF 15 PATIENTS LIVING FIVE YEARS

	CASES
Epidermoid carcinoma	
Grade [illegible]	6
Grade [illegible]	1
Grade [illegible]	1
Adenocarcinoma	3
Undifferentiated carcinoma	2
Carcinoma simplex	1
Not typed	1

SUMMARY AND CONCLUSIONS

This study is a review of 160 carefully followed cases of carcinoma of the lung. The conclusions are the following: (1) The present day therapy of carcinoma of the lung, though leaving much to be desired, yet clearly establishes the sound [illegible] resection. Thus 9.5 per cent of all cases and [illegible] of those given curative resection survived five years or longer [illegible] mortality for all the years of 7.6 per cent. (2) The emphasis must be placed increasingly on patient and practitioner awareness Only in this way can the long interval between onset of symptoms and resection be shortened (3) Further research is indicated before we can state with any assurance the etiological factors involved in the various types of cancer of the lung (4) High-voltage radiotherapy may have something to offer as an adjunct to surgery in the treatment of bronchogenic carcinoma (5) Those who have the opportunity should persistently strive to bring about more chest surveys with complete follow-through and careful attention to all intrathoracic symptoms until they are fully explained

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DISCUSSION

DR JOHN H GIBBON, Jr, Philadelphia, Pa—I am always impressed with the similarity of the results obtained in different series, Dr Boyd's results are quite similar to ours over the past seven years We have seen that up to Jan 1, 1954, there were 635 consecutive histologically proved carcinomas of the lung at the Jefferson Medical College Hospital in a period of seven years I do not think the survival figures are too bad. Although only 9 per cent of all patients we have seen are alive five years later, in the group of patients in whom the tumor was removed (39 per cent of our entire series), we have a 26 per cent five year survival This is very similar to the series of Ochsner and DeBakey, and I think compares quite favorably with the five year survival rate of gastrectomy for carcinoma of the stomach In the cases where the cancer was confined to the lung our results are similar to Dr Boyd's, i e, over 40 per cent five year survival. In other words, if we can operate before the cancer has spread beyond the lung we have a respectable percentage of five year survivals I do not think we should be too pessimistic about these statistics At the present time the results of operation are as good as if not better than the results of operation for carcinoma of the stomach

DR RICHARD H OVERHOLT, Brookline, Mass—The precipitous rise in the rate of carcinoma of the lung as a cause of death makes this subject before this Association particularly significant, I think As Dr Gibbon said, the results of Dr Boyd and of others add up to about the same It was interesting to us to find in reviewing our cases that of 60 patients operated on before 1951 who are living today one third had had a palliative resection This encouraged us to extend exploration in all cases where there is not positive evidence of extension beyond the lung I cannot quite agree however with Dr Boyd s enthusiasm about x ray therapy

We have checked back over a ten year period and find that patients to whom we have given x ray therapy have not lived as long as the ones that did not have it In patients who had no thoracotomy all histologically proved cases, we find that the irradiated patients lived an average of ten months from the first symptom whereas patients who had no treatment at all lived on an average of thirteen months So by attempts at palliation, we did not actually prolong life

In patients in whom we did an exploratory operation only, followed by x ray therapy the average length of life was fourteen months and, in the untreated thirteen months In other words, in this group, those given irradiation were given but one month more to live and possibly suffer. We are not at all encouraged by this experience. I am not sure it is kind to punish the patient by radiation sickness during his terminal few months of life.

In the last consecutive 100 cases, most of them done in 1953, we explored 71 per cent and resected a lobe or lung in 46 per cent. We have done palliative resections in 31 per cent and curative resections—in cases where we could find no evidence of tumor outside the lung—in 15 per cent.

Prior to 1950 we treated a group of 30 patients for silent lesions. There were only 8 treated within three months of the first x-ray in that series; 6 are living today. There were 22 patients treated for silent carcinoma, but exploration had been delayed for several months; there are only 5 patients of that group living. This emphasizes again the fact that our best hope is to support all the survey programs and explore all suspect cases promptly.

DR. JOHN C. JONES, Los Angeles, Calif.—I should like to say a few words regarding my experience with carcinoma of the lung over an eleven-year period from 1942 through 1952. During that time my associates, Dr. Robinson and Dr. Meyer, and I saw 639 private patients with proved carcinoma of the lung. Of those, we considered only 300, or 48 per cent, to be clinically operable.

Twenty-five of these either refused operation or went elsewhere, so that actually only 275, or 44 per cent of the diagnosed patients, were explored, and only 144, or 23 per cent, had resections.

We wanted to see what our five-year follow-up would be. Prior to 1948 there had been 286 cases diagnosed. Of the 286, there were 41.6 per cent operated on, and 60, or 21 per cent, had resection, which of course includes the so-called palliative resections. Our over-all salvage rate is lower than that presented here. Only 17 patients, or 5.9 per cent of those diagnosed, are either alive today or died of causes other than carcinoma. Only 11 patients, or 3.8 per cent of the 286 diagnosed, are still alive. It is interesting to note in this group that two patients died after the five-year survival period, one seven and the other nine years after resection, both dying of metastatic or recurrent carcinoma of the lung.

The thing that discourages me is that we continue year after year to see so many patients who are not operable. We seem to be doing more and more extensive resections on patients who have more and more carcinoma, and I do not believe we are seeing these patients any earlier now than we were five years ago. Our operative mortality rate among the patients resected over the eleven-year period was only 4.9 per cent, but with a salvage rate of only [illegible] per cent it seems to me to be a discouraging picture.

DR. ALTON OCHSNER, New Orleans, La.—I wish this discussion could be heard by the Academy of General Practice as well as our group. We have some statistics regarding the time at which these cases are seen. Actually, there is a longer delay today between the onset of symptoms and definitive therapy than there was five years ago, and it is [illegible] unquestionably due to the fact that these people are being treated for viral pneumonitis. Interestingly enough, it is longer in the private series than in the charity series. There is an average delay of about six months in the private series as compared with three [illegible] in the Charity Hospital series. In other words, a person who is not able to afford [illegible] comes to the Charity Hospital and has the diagnosis made in about half the time.

Our [illegible] are [illegible] as Dr. Boyd presented. In a total series of [illegible] cases [illegible] 10 per cent mortality rate. We feel that palliative resections are [illegible] palliative [illegible] resection in the cases in which there is extension [illegible] broad application, but actually if one accepts this [illegible] The [illegible] of cases showed extension beyond the lung [illegible] period [illegible] 12 per cent, much higher than has been previously reported Of the hospital deaths, 45 per cent were cardiovascular; 30 per cent were respiratory, 8 per cent were due to hemorrhage These are the statistics that I would like to refer to in particular One sees our over all five year salvage rate, this includes everyone subjected to operation or not operated upon, and everyone dying regardless of the cause of death *When one recalls that at this age only 85 per cent of* the population are alive at the end of five years, we have a five year salvage rate of 15 per cent in the resected cases as contrasted with a group of cases in which no operation was done, *in which only one of 500 patients is alive four years after therapy That one* patient received nothing but nitrogen mustard, and he is the only one in the nonresected group who has lived that long

When one contrasts *the* so called palliative and the so called curative resections, one finds that in the group of palliative resections about 7 per cent are alive These are patients that I think would have been turned down by most thoracic surgeons, and we are very proud of even such a small group *In this* curative resection group, 34 per cent are alive five years after resection

To recapitulate the whole series, there were 55 per cent that were operable and 32 per cent resected, 26 per cent survived resection, with a five year survival rate in the *entire group of 6 6 per cent I will not mention my ideas about smoking as a cause, for* most of you know what they are, I think when the final page is written you will find that smoking is the real cause

DR JOSEPH GORDON, Albuquerque, N M.—Although I have moved from upstate New York *to the Southwest, I have maintained my interest in this problem* I have been asking about the incidence of carcinoma in the Indian, and have found some surprising answers I wrote to Dr Graham asking him what he thought of it He said we might *go on and consider it as a problem that may be of real value for study*

This is what I have learned On a Navajo Reservation at Fort Defiance there is a 100 bed general hospital In the past three years an enthusiastic group of physicians have been looking for carcinoma in all organs They have reported to me *that in a* review of all cases entering this hospital, they have yet to see carcinoma of the lung in these Indians although it has been found in their other organs They also said that in reviewing a twelve year study of hospital records they have not found any *recorded* cases of carcinoma of the lung This obviously brought up the question of smoking by the American Indian, whom we often blame for establishing the habit I learned that they smoke very little the older people particularly They make a package of *tobacco* like Bull Durham last for a week or more Smoking, therefore, is not very common on the reservation This would be in contrast, I am sure, to the *off* reservation young people who appear to be taking up the habit of smoking a great many cigarettes *I think* that if the members of this Association were to interest themselves in this problem it might help us in a long term study of the subject

DR ARTHUR H AUFSES, New York N Y —I would like to review some figures compiled from a fourteen year survey at the Mt Sinai Hospital in New York City It runs from 1935 through 1948, and therefore includes the worst years of carcinoma of the lung surgery and excludes the best years, those since 1948 We ended it in 1948 because we wished to have a five year follow up The Mt Sinai Hospital is a general hospital and therefore this is a picture of carcinoma of the lung as it occurs in the general population in New York City

We saw 959 cases of carcinoma of the lung in this fourteen year period We reviewed them in relation to the duration of symptoms before operation and we had 32 patients who had no symptoms *Their* tumor was discovered either *on* survey or on fluoroscopy in a doctor's office In that group we had 44 per cent resectable cases There are five patients of the 32 who are alive and well and considered cured If you look at the duration of symptoms before operation you will see that there is little difference in resectability whether the symptoms were present for less than one month or as long as three years.

In no patient with or without node involvement was radical mediastinal dissection performed. In the patients with node involvement there is a 6 per cent cure rate and in those without involvement there is a 30 per cent cure rate. This of course is to be expected.

We did about one third lobectomies: of 165 resections 53 were lobectomies. In the lobectomies 26 per cent are considered cured and in the pneumonectomies only 17 per cent are considered cured. Of course lobectomies are done for small lesions limited to one lobe and without gross lymph node involvement at the time of operation.

DR. DAVID P. BOYD (closing).—I shall not try to reply to the discussants individually. They are all men of vast experience in this field and I really feel that many of the points of apparent difference are differences of viewpoint, perhaps even differences of temperament. We certainly need Dr. Gibbon's optimism in this distressing field. If I impressed Dr. Overholt as being very optimistic about any form of radiation therapy, I did not mean to be particularly enthusiastic. It may be an unconscious reaction on my part from the last time I gave a similar talk a few weeks ago in a southern city. After the talk was finished one of the discussants called me a cynic—in the politest of tones of course—and I remembered a line in one of Shaw's plays in which one of the characters says: "The power of accurate observation is called cynicism by those who do not possess the faculty." If that is so I am content to be a cynic.

A CLINICAL SURVEY OF ADENOMAS OF THE TRACHEA AND BRONCHUS IN A GENERAL HOSPITAL

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Although the existence of endobronchial tumors other than bronchogenic carcinomas has been recognized for many years, their rarity has delayed the accumulation of sufficient clinical data to characterize them with certainty. The application of the term *adenoma* to a variety of neoplasms unrelated in either cellular pattern or clinical behavior has made matters worse. It has led to similar treatment for dissimilar tumors and particularly to the employment of indiscriminate radical surgery for lesions of both low and high degrees of malignancy. At the present time most pathologists recognize the *carcinoid adenoma* and the *cylindroma* as separate entities on the basis of their cellular patterns. In reviewing our own experience, we have studied only those cases in which the histologic pattern fell definitely into one of these two groups. Other tumors such as basal cell carcinomas and mixed tumors (similar to mixed tumors of the parotid) have been excluded as being microscopically different. All of the lesions which contained tissue resembling bronchogenic carcinomas histologically were classified and treated as such.

In the presentation of these cases the cylindromas have been separated from the carcinoid adenomas because the two categories have nothing in common either pathologically or clinically. The entire hospital experience with these growths regardless of treatment, is presented here in an effort to correlate the courses of the patients with the malignant potential of their tumors. Over the period of years 1909 to 1954, there were 56 carcinoid adenomas and four cylindromas diagnosed at the Massachusetts General Hospital. The follow-up has been complete, a point of major importance in any study subject to statistical analysis.

PATHOLOGY

The original microscopic diagnoses of the tumors presented in this series were carefully scrutinized. When necessary, fresh slides from the original specimens were made. No tumor which had been identified originally as an adenoma was found to be a bronchogenic carcinoma, but at least five tumors which had been classified as "low-grade carcinomas" were reclassified as carcinoid adenomas on the basis of this study.

Carcinoid Adenoma.—Microscopically, all 56 of the carcinoid adenomas of this series fitted into the standard pattern for the disease. Basically they were

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Read at the Thirty-fourth Annual Meeting of The American Association for Thoracic Surgery, at Montreal, Quebec, May 3 to [illegible], 1954.

composed of small polygonal epithelial cells of uniform dimensions with a finely granular acidophilic cytoplasm (Fig. 1). The nuclei were round or ovoid and contained a fine chromatin precipitate; visible nucleoli were uncommon. The cells were arranged in anastomosing columns of varying diameter or in small masses suggestive of acinar grouping. Uncommonly true acini were formed without visible content or were filled with a nonmucinous finely granular protein precipitate. The cell columns and groups were intimately associated with many sinusoids presumably of both vascular and lymphatic origin. A delicate fibrous stroma enclosed the sinusoids.

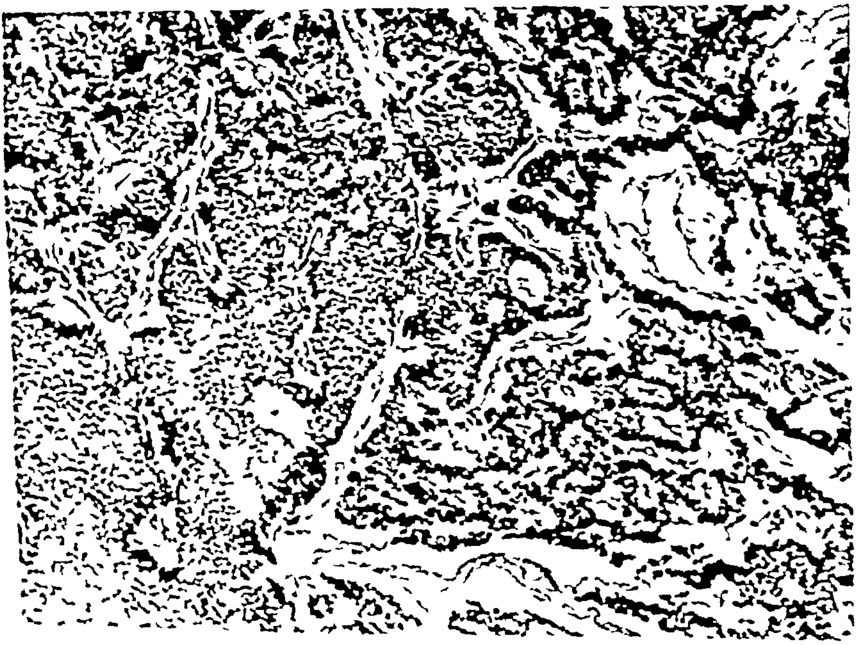


Fig. 1. A typical [illegible] adenoma composed of anastomosing columns of uniform cells. The intimate association of the columns with numerous sinusoids is apparent.

Some variations were usually evident in the basic pattern. Some tumors contained nuclei that varied considerably in size and had occasional giant forms. The latter were reminiscent of the giant nuclei found in many parathyroid adenomas. Bone spicules could be found in some of the tumors apparently arising in an included bronchial cartilage or in the stroma itself.

Evidence of malignant activity was manifested by the following. First, mitoses, although distinctly rare, were found in six tumors. Second, there was microscopic evidence of penetration of the tumor through the capsule into adjacent lung in 25 of the [illegible] encapsulated tumors in which this could be examined. Third, secondary deposits of tumor in adjacent lymph nodes were found in three patients. In one patient there was a single metastasis in one out of [illegible] lymph nodes submitted with a resected left lung; invasion of a lymphatic [illegible] was found in this case. In another two out of five lymph nodes [illegible] tumor in a specimen consisting of two lobes of the right lung. In the third, whose autopsy followed death from pneumonia, a lymph node measuring 2 by 3 cm. was found to be replaced almost totally by tumor. This case was reported by Holley.[1] On microscopic examination the metastasis was similar morphologically to the tumor which had been removed from an adjacent bronchus by an endoscopist at intervals of two, four and six years previously. At post-mortem examination no residual tumor was apparent in the bronchus. Although blood vessels were occasionally compressed by these adenomas, none were invaded and there was not a single case of hematogenous spread.

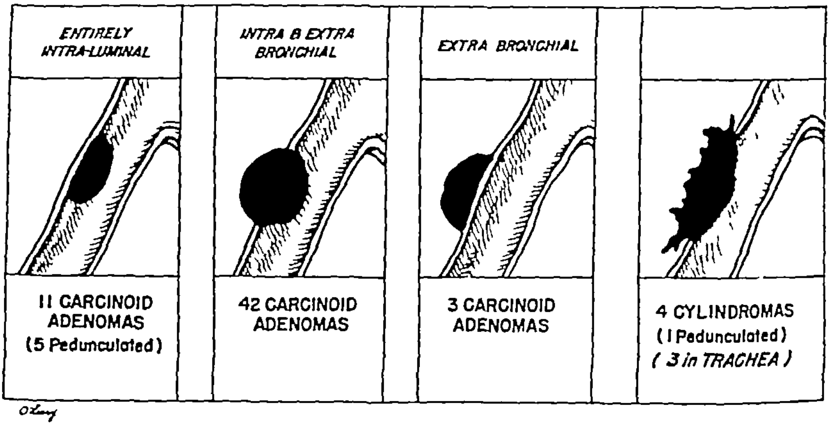


Fig. 2.—Schematic drawing showing relationship of carcinoid adenomas and four cylindromas to the wall of the bronchus and trachea.

Grossly these tumors appeared to be well circumscribed and noninvasive. Their positions in relationship to the bronchial wall and lumen are shown in Fig. 2. The main tumor mass was either polypoid, sessile intramural, or extramural. The most common mode of growth produced a small intrabronchial protrusion and intramural invasion with the bulk of the tumor lying outside of the bronchus. Only eleven of the tumors appeared to be entirely intrabronchial and superficial to the bronchial cartilages. Only five were actually pedunculated. Pedunculation was often deceptive because some neoplastic cells usually penetrated through the bronchial wall. In three cases tumors arising at the bifurcation of a bronchus extended in fingerlike cylinders down both dilated bronchi but remained intrabronchial. In no instance was the extrabronchial tumor mass greater than 4.5 cm. in diameter. Three tumors lay entirely outside of the cartilage plates.

Intermittent or complete obstruction of bronchi by these growths often caused considerable pulmonary suppuration with irreversible pathologic changes. In brief, as demonstrated either radiographically or by examination of tissue removed at operation or at autopsy, 33 patients had bronchiectasis, 20 had pneumonitis, 11 had empyema, 5 had lung abscesses, 2 had acute bronchitis, and 2 had pulmonary fibrosis. Only 7 out of 56 patients had no evidence of permanent pulmonary damage.

Cylindroid Tumors.—Cylindromas, found most commonly in the trachea, but also occurring in major bronchi, bear little resemblance to carcinoid tumors. Though similar on gross inspection, the invasive nature of the cylindroma is usually apparent. Like carcinoid adenomas they may have a polypoid intraluminal mass with or without extension through the wall of the airway to form an extramural projection. When the tumor extends beyond the wall of the trachea or bronchus no capsule developes and invasion of neighboring structures occurs.

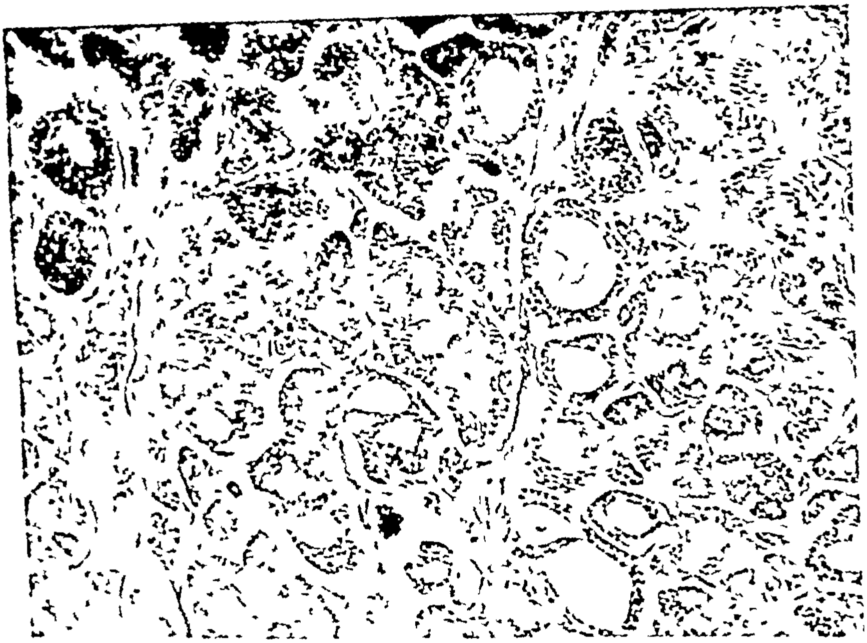


Fig. [illegible] A cylindromatous tumor forming acini filled with mucinous material. The conformation is [illegible] reminiscent of mucous gland ducts.

The basic structure of the cylindroma is a series of branching tubules and acini embedded in relatively avascular connective tissue of varying density and abundance (Fig. [illegible]). Frequently the acini contain mucinous material. The typical cell is small and uniformly basophilic. Mitoses are more common than in carcinoid adenomas.

In three patients in this series the cylindroma originated in the trachea. One was pedunculated but invaded the wall of the trachea and no capsule had formed. The second invaded the wall of the trachea almost in its entirety, extending into the thyroid gland but producing no mucosal ulceration. The third tumor invaded the thyroid with fingerlike projections. In a fourth patient the cylindroma originated in the right intermediate bronchus and had already spread to the lobar bronchi when a right pneumonectomy was performed. Over thirteen years later after tumor recurrence and at autopsy there was invasion of trachea, pericardium and left main [illegible]. Residual tumor was found in the stump of the right main bronchus. The left main bronchus was encircled by the growth as was the esophagus and superior vena cava. The most interesting attributes of these cylindroid neoplasms were their benign appearance, cellular uniformity, paucity of mitoses and remarkable ability to invade the perineural lymphatic channels.

SEX AND AGE

In this series 31 males and 25 females had carcinoid adenomas; their average age at the onset of symptoms was 33.1 years. Three patients dated the onset of their symptoms from the time when completely asymptomatic lesions were removed because abnormal routine chest roentgenograms had led them to seek medical advice.

The time of diagnosis for the 56 patients was established as follows: For four it was the time when a shadow was first observed roentgenographically which was later found to be consistent with carcinoid adenoma and was ultimately removed. For one, it was established by bronchoscopic observation and subsequently confirmed by resection. For the remainder it was the time when the diagnosis was first made on the basis of microscopic section.

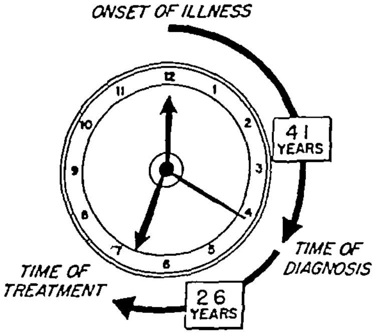


Fig. 4.—The average delay in years between onset of symptoms, time of diagnosis and operation for 45 patients who underwent definitive surgery for carcinoid adenoma.

The average age at the time of diagnosis was 37.9 years, the youngest was a 10-year-old girl and the oldest a 76 year old man. At the onset of symptoms the average age was 33.1 years. This is a difference of 4.8 years with a minimum of 0 and a maximum of 20 years. In considering only those 45 patients whose carcinoid adenomas were removed surgically, the average age at the onset of illness was 32.2 years, at the time of diagnosis it had risen to 36.3 years but by the time of definitive surgery it was 38.9 years. The delay in years between those ages is shown graphically in Fig. 4.

Of the four patients who had cylindromas, two were males and two females. Their ages at the time of diagnosis were 35, 36, 63 and 65 years respectively.

SYMPTOMS

Although no specific symptoms serve to identify endobronchial tumors,[1] a prolonged history of pulmonary infection, cough and hemoptysis in a young adult may arouse the suspicion that an adenoma is present As the disease develops over the years the symptoms will change particularly if pulmonary infection becomes chronic In general the symptoms fall into three groups those immediately referable to the presence of a tumor in an airway those associated with infection of the lung and last the reactions of the body as a whole to pulmonary suppuration and collapse In the first group we find cough hemoptysis and wheeze in the second bouts of pleurisy, bronchitis, and pneumonia in the third chills fever malaise weight loss and dyspnea The most prominent symptoms have been outlined in Table I

TABLE I 56 PATIENTS WITH CARCINOID ADENOMAS FREQUENCY OF MAJOR SYMPTOMS

COMPLAINT	FREQUENCY	AS INITIAL COMPLAINT	AS CHIEF COMPLAINT ON HOSPITAL ENTRY	NONE
Cough	52	21	19	4
Hemoptysis	39	13	15	17
Wheeze	4	0	1	52
Bouts of pneumonia	36	11	8	20
Bronchitis	4	0	0	52
Pleurisy	9	6	5	45
Dyspnea	4	0	1	52
Fever	9	2	4	—
None		—	—	—

It is noteworthy that cough both hacking and productive, was a very common symptom Blood streaked sputum was reported by 28 patients but massive bleeding (several ounces or more) by only 11 In one form or another bleeding was complained of by 17 out of 18 patients whose symptoms were of ten years duration or more It is interesting to note that of the 28 patients who had bleeding there were only three in whom no pathology other than the adenoma was demonstrable The systemic symptoms were rarely the basis of chief complaints

The three patients with tracheal cylindromas complained of dyspnea on inspiration the one with a bronchial lesion complained of cough

DIAGNOSIS

Roentgenographic—Roentgenographic findings are of major importance in establishing the diagnosis of adenoma Even routine or survey methods will usually indicate the presence of some abnormality Because of the many years spanned by this series the films of only 46 patients are still available In nearly half of these it was possible to visualize a portion or all of the tumor [illegible] In the remainder only those changes associated with bronchial obstruction were seen The most commonly associated conditions are collapse bronchiectasis acute pneumonitis or lung abscess Collapse was demonstrable in [illegible] of the 46 cases and bronchiectasis with or without collapse in 26 Bronchiectasis was demonstrated more often on plain films than by bronchography [illegible] many dilated bronchi could be readily distinguished from surround[illegible] when pneumonitis or collapse was pres[illegible] the injection of opaque media into the bronchi

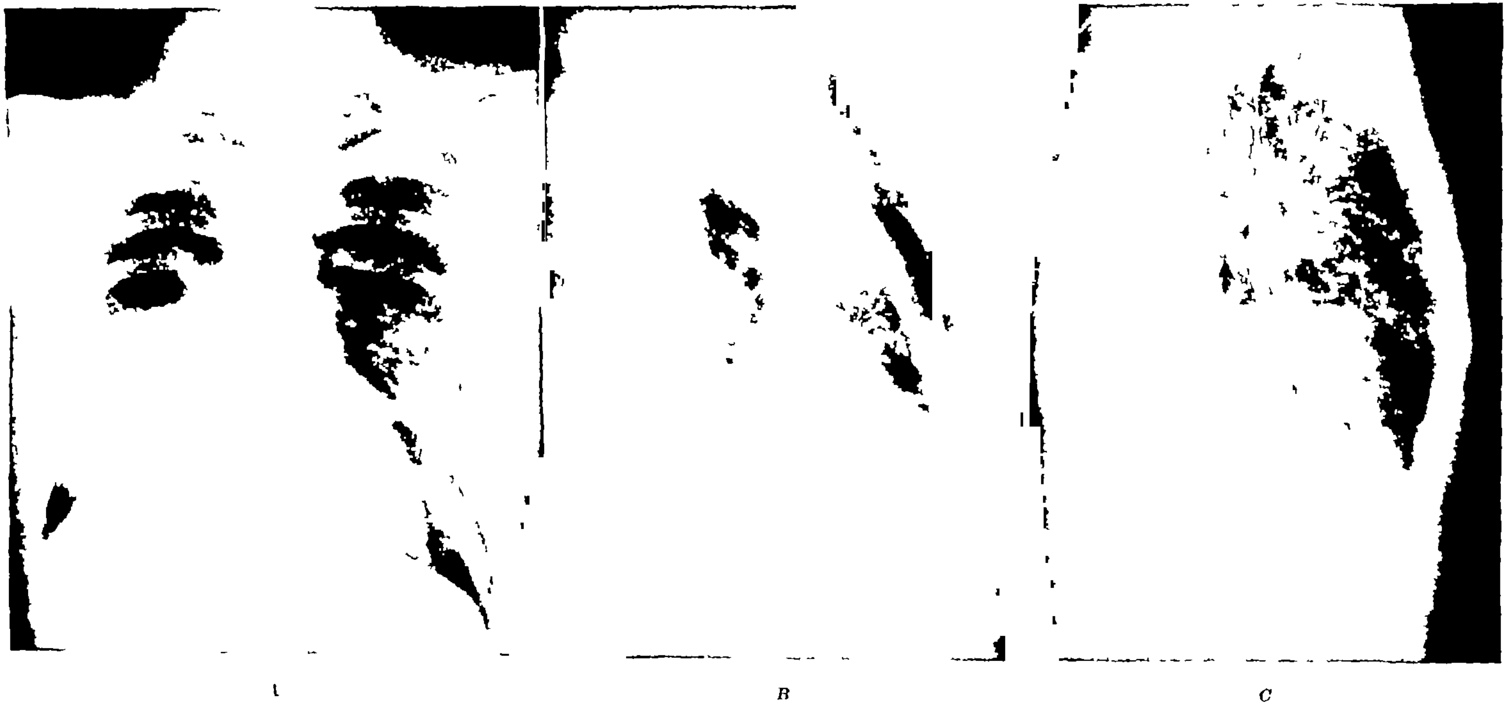
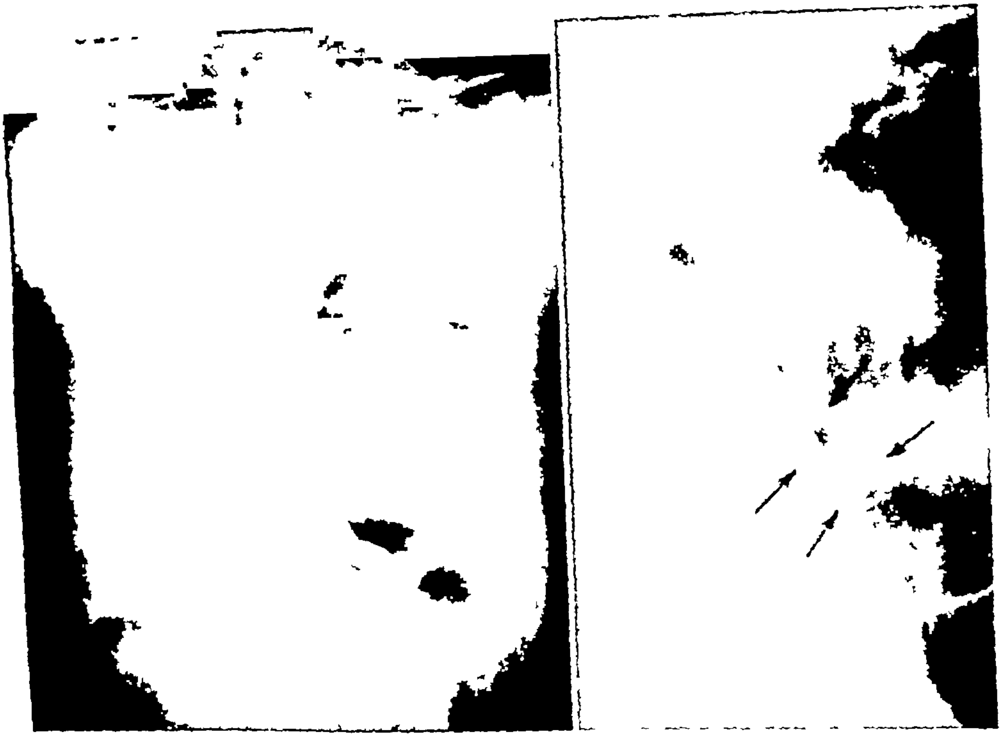


Fig. [illegible].—A and B, Carcinoid adenoma in a bronchus. Note the collapsed right lower lobe lying posteriorly in the lower portion of the right chest. Within the superior portion of the area of density several small bubbles are noted which suggest the possibility of abscess. There is evidence of old rib resection. C, Lateral bronchogram reveals a mass in the right lower lobe bronchus just below the middle lobe orifice.

tative resections could not be accomplished because of obstruction produced by the tumor. In only a few cases was the bronchial obstruction recognized in its early stage when obstructive emphysema was the primary finding.



[illegible] [illegible]

[illegible] of left main bronchus. Opacity of the right chest as a result [illegible] Note the displacement and involvement of the [illegible] narrowing of the left main bronchus throughout its [illegible] and wall of the left main bronchus is more [illegible]

In half of the cases the tumor mass was obscured by an inflammatory reaction in the adjacent lung; in the remainder it was possible to identify the tumor. Its size, which could then be approximated, varied from a few millimeters to several centimeters in diameter. Usually the mass was of homogeneous density; ossification or calcification was demonstrable within the tumor mass in [illegible] cases. In no instance was central necrosis seen. The observable portion of the tumor was usually smooth in outline or slightly lobulated, round or ovoid in shape, and submucosal or extrabronchial extension was [illegible] clearly demonstrated. The intraluminal mass as contrasted to that of [illegible] of the larger bronchi appeared to be rounded like [illegible]. The large extrabronchial extension of some carcinoid [illegible] secondary tumors of other types.

[illegible] were dismissed because of their irregular infiltrating [illegible] long narrow segments of trachea or bronchus (Fig 6) There was no evidence of pathologic changes in the lung distal to the tracheal cylindromas, bronchiectasis was associated with a cylindroma which had arisen in the right intermediate bronchus

When only films of high contrast were obtained actual demonstration of a tumor mass which lay in the lumen of a major bronchus was often impossible To outline the trachea and major bronchi clearly, a high kilovoltage technique was employed and at least one posteroanterior or anteroposterior projection using a grid or Bucky diaphragm was obtained In addition it was essential that the patient be fluoroscoped Spot films were helpful and laminagraphic studies were occasionally of great importance In a few instances it was necessary to resort to bronchography for actual demonstration of the tumor but this latter method has been abandoned for the most part in favor of laminagraphy

Bronchoscopic.—If a transthoracic excision of a tumor is planned it is exceedingly helpful to the surgeon to have the roentgenographic findings and the history suggestive of adenoma, confirmed by biopsy Thirty-five of the carcinoid adenomas and both of the resected cylindromas were thus identified before resection (A histologic diagnosis for every tumor was ultimately obtained by bronchoscopic biopsy in 46 at operation in 11, and at autopsy in 3)

Radical surgery was avoided in three instances in which it would have been undesirable because preoperative bronchoscopic observation indicated that the tumors were carcinoid adenomas Five other tumors resected thoracically were too peripheral to be seen at bronchoscopy

The final decision as to the type and extent of treatment depends on the accuracy of diagnosis

TREATMENT

Radiation Treatment.—Experience with radiation therapy of either the carcinoid or cylindromatous type of adenoma has been limited in this hospital In all there were eight patients who received some form of radiation therapy at some time during the course of their disease All of these were treated in or prior to 1938 before the present day concepts of dosage determination were in effect In consequence the total doses delivered cannot be estimated with accuracy

Three patients were treated by insertion of radon seeds into the tumor through the bronchoscope the remainder received varying amounts of x ray (Only three of them were treated at this hospital)

Extensive discussions of the use of radiation therapy in carcinoid adenoma of the bronchus have not been found In most reports there is only an occasional case mentioned in which radiation therapy had been used This lack of information plus the small number of patients treated in such a manner in this series particularly in view of the lack of accurate dosage measurement makes it impossible to evaluate radiation therapy However even though the tumor might respond to radiation treatment the associated damage of the distal lung or bronchi would receive no benefit. From theoretical considerations and limited experience, therefore, radiation therapy offers little permanent value, and surgical extirpation evolves as the treatment of choice.

In the treatment of cylindromas, which are most often located in the trachea, a trial course of radiation therapy with the hope of producing a good regression may be justified. Should this be unsuccessful, there would be sufficient opportunity for later surgical intervention. From the little information now available, it is assumed that reasonably large tumor doses might be necessary. Too little factual knowledge is at hand, however, to justify drawing any conclusions.

Operative Treatment.—Apparently complete operative resection of the tumor was carried out in two patients with cylindromas and in 45 with carcinoid adenomas. During the 1920's and early 1930's, when thoracic surgery was hazardous and the malignant potential of the adenoma unconfirmed, bronchoscopic resection was the treatment of choice. Only one patient in this series, a man whose carcinoid adenoma was removed and the base implanted with *radon* seeds bronchoscopically in 1932, was both cured of the tumor and escaped distal lung damage. In three others the local removal of tumors was apparently complete, but subsequent lobectomies were necessary because of chronic pulmonary sepsis. Transthoracic procedures at first were limited to the drainage of empyemas or lung abscesses, but gradually lobectomy and pneumonectomy were introduced for the treatment of uncontrollable infection or hemorrhage. Following the first cure by lobectomy in 1931, the direct approach to the problem became increasingly popular. Bronchoscopic resection has been gradually relegated to the treatment of the bad-risk patient. Since 1945 only one patient, a man of 70 who was a very poor risk for any other type of surgery, has been so treated.

The extent of the resection must be determined in each instance at the time of operation. In this series the rounded noninvasive nature of the carcinoid adenoma and the lack of obvious metastasis (in all but two cases) were deciding factors. In both of the patients with lymph node involvement the condition was recognized when the chest was opened and adequate resections were therefore performed.

All of the carcinoid adenomas in this series have been technically operable. Two of the four cylindromas, because of the extent of the tracheal involvement, were not. Of the two removed, one was by a partial tracheal resection and the other by a right pneumonectomy.

Fig. 7 depicts the operative procedures schematically. In the carcinoid group there were 27 tumors in the left bronchial tree and 29 in the right, but [illegible] pneumonectomies were performed on the left and only two on the right. [illegible] the left main bronchus was partially responsible for this dis[illegible] in addition [illegible] tumors at or close to the bifurcation of the left upper and lower lobes usually required removal of both lobes. A similar situation [illegible] at the right middle and lower lobe bifurcation [illegible]. Tumors arising in the right intermediate bronchus were treated similarly There were 11 of these bilobectomies When they are added to the right pneumonectomies, the total equals the number of left pneumonectomies It is interesting to see how frequently permanent changes in lung tissue associated with the tumors necessitated resection of lung tissue Complete or partial destruction of two lobes from previous infectious processes led to seven pneumonectomies and nine bilobectomies

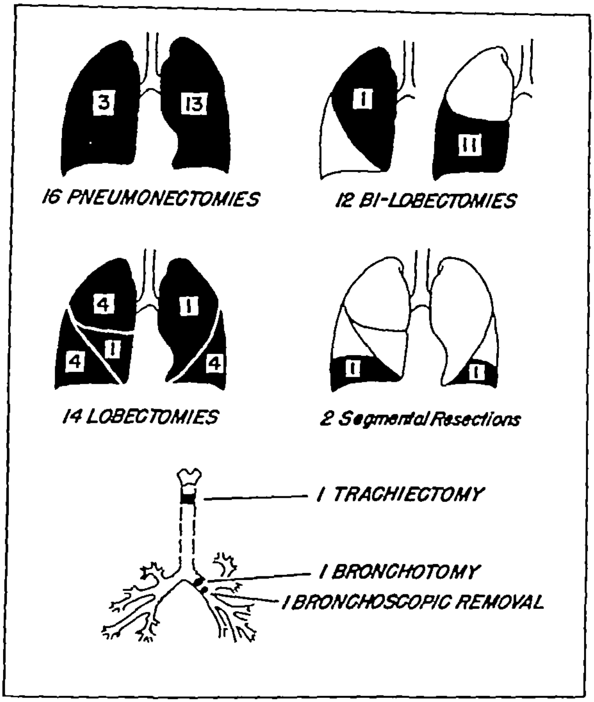


Fig 7 —Schematic drawing showing the areas of resection for two cylindromas (one by trachectomy and one by right pneumonectomy) and for 45 carcinoid adenomas

Technical difficulties caused by the size of the tumor or its proximity to the interlobar bifurcation prevented preservation of a normal lobe in all of the remaining cases, in only one case, that of a right pneumonectomy, was there normal lung tissue in all of the lobes The long delays from the onset of symptoms to the time of extirpative surgery were probably directly responsible for the necessity of sacrificing so much tissue in so many instances

Interestingly enough two of the pneumonectomies were staged Both patients were first treated by left lower lobectomies (using the tourniquet technique) because of severe pulmonary suppuration The tumors were not included in the specimens A year later (1936) the remaining lobe and the adenoma were resected for one patient because of continued infection The growth was in the main bronchus and the man died postoperatively Fifteen years later the remaining lobe and tumor were removed from the other patient because of hemoptysis The tumor was in the stump of the lower lobe bronchus this patient is alive and free of disease at present Neither had metastases

In one instance when the adenoma lay partially in both the upper and middle lobes and the fissure between was incomplete, excision of both lobes was carried out. Single lobectomies were performed in 14 instances, in only two of which did technical reasons demand removal of so much tissue. In the others it was because of irreversible pathologic changes in the lung. Recently, because patients have been referred much earlier in the course of their illnesses, it has been possible to treat two patients by resecting the basal segments of a lower lobe and one by a partial resection of the left main bronchus. None had detectable lymph node metastases nor any permanent damage in their lung tissue.

The postoperative course of these patients expressed in both complications and operative mortality reflects the progress of thoracic surgery. The first resection, a right lower and middle lobectomy, was performed by Dr. Edward D. Churchill in 1931. The patient recovered and is living and well over twenty-two years later. During the 1930's sepsis was a considerable problem. The only two operative deaths, both after lobectomies and both from sepsis, occurred during this era, the last in 1936. Complications diminished rapidly after the advent of the antibiotics and since 1945 have been of only minor consequence. In our whole group 45 transthoracic resections have been carried out with an operative mortality of two cases or 4.5 per cent.

RESULTS

No study of the effects of tumors upon their human hosts can be of value unless the basic histology of the growths consistently follows a pattern acceptable to pathologists and the follow-up of the patients is both long and absolutely complete. The addition of tumors of dubious or unrelated histology and the loss of a single case to follow-up can invalidate the statistical conclusion of a small series. We are presenting, therefore, a follow-up on all patients who have entered the hospital between 1908 and 1954 with carcinoid and cylindroid tumors. The results have been analyzed for the group as a whole, for those who have died, for the untreated patients and for those who underwent definitive surgery.

Out of 56 patients who had carcinoid adenomas 41 are living. For 45 patients the diagnosis was made long enough ago (before 1949) that they could have lived for at least five years subsequently. Thirty-three, or 73.3 per cent, have survived five or more years irrespective of whether or not they received any therapy. Of the four patients with cylindroid tumors three were diagnosed long enough ago to permit a five-year survival; all of them lived at least that long irrespective of treatment; two are now alive. In surveying the cases of microscopically proved bronchogenic carcinoma, regardless of whether the patients received therapy or not, we found that in a comparable period of time only 15 out of 366 or 4.1 per cent survived five years or more. In Fig. [illegible] the survival rates for bronchogenic carcinoma and carcinoid adenoma are presented.

Perhaps the most reliable means of determining whether the malignant [illegible] of the histological pattern of a tumor are warranted is by study of the causes of death for the patients who have been afflicted with the disease (Table II), fifteen patients in this series who had carcinoid adenomas have died, ten were autopsied. The causes of death in the five who were not examined post mortem are as follows. One patient, whose tumor was not resected, died of pneumonia at the age of 72. Another, a young woman of 32, died at home of hemorrhage a few days after a bronchial biopsy. Three others died at four, four and seven years, respectively, after lobectomies; none of the three had had recognizable lymph node involvement at operation. The causes of death among them were cerebral hemorrhage in a man of 66, arteriosclerotic gangrene of the leg and diabetes in a man of 81, and cardiac failure secondary to arteriosclerotic heart disease in a man of 61. These patients had been followed in our clinic as well as being cared for by their own doctors. No clinical evidence of metastases was ever established, but the presence of residual disease cannot be completely excluded.

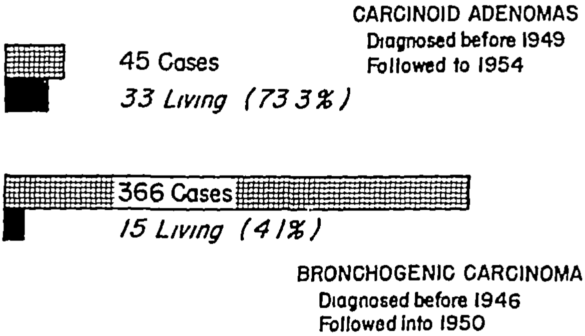


Fig. 8.—Comparative five year survival rates for patients with bronchogenic carcinoma and carcinoid adenoma. All cases treated and untreated are included. None of the deaths in the adenoma group came from the tumors themselves.

Of the ten patients upon whom autopsies were performed (Table II) only one showed any evidence of metastatic disease. This man, whose tumor had been removed locally by bronchoscopy two years previously and who had also received a short course of roentgen therapy, died of pneumonia. At post-mortem examination six years after the diagnosis had been established there was no microscopic evidence of residual bronchial disease, but there was a single metastasis in an adjacent lymph node. Four patients who had been treated by pulmonary resection were autopsied; two had died postoperatively. Another died of an adrenal carcinoma two years after resection of the lung and three years after the establishment of pulmonary diagnosis. The fourth died of a scirrhous carcinoma of the stomach two years after lobectomy.

The cylindromas, by contrast, although slower in development and less lethal immediately than bronchogenic carcinomas, were far more malignant in behavior than the carcinoid adenomas. Two patients with cylindromas died and were autopsied. In one, death was due to asphyxia despite the insertion of a metal airway to relieve the obstruction caused by tumor which had extended the length of the trachea and had invaded surrounding structures. The other, who had had a pneumonectomy over thirteen years previously for a tumor arising in the right intermediate bronchus remained asymptomatic postoperatively until a few months prior to re-entry. He was then re-explored with the hope of resecting a local recurrence which had partially occluded his left main bronchus. Widespread local metastases rendered extirpation of the tumor impossible. At autopsy a few days later evidence of extensive recurrence in the mediastinum was confirmed. No distant metastases were found in this patient or in the other one.

TABLE II. CAUSE OF DEATH IN 15 PATIENTS WITH CARCINOID ADENOMAS, 2 WITH CYLINDROMAS

YEAR	AGE	YEARS OF SURVIVAL AFTER ONSET OF ILLNESS	YEARS OF SURVIVAL AFTER DIAGNOSIS	AUTOPSY	METASTASES	CAUSE OF DEATH	TYPE OF TUMOR
[illegible]	40	3	0	Yes	0	Pneumonia	Carcinoid
1927	21	4	4	Yes	0	Pneumonia	Carcinoid
1934	19	2	⅓	Yes	0	Postop. sepsis	Carcinoid
1936	36	3	2	Yes	0	Postop. sepsis	Carcinoid
1936	67	½	0	Yes	0	Actinomycosis	Carcinoid
1941	52	4	⅓	0	—	Hemorrhage	Carcinoid
1941	43	14	4	Yes	0	Ca. of colon	Carcinoid
1944	29	14	6	Yes	1 Lymph node	Pneumonia	Carcinoid
1942	40	[illegible]	3½	Yes	0	Ca. of stomach	Carcinoid
1945	61	28	7	0	—	Cardiac failure	Carcinoid
1947	40	19	2	Yes	0	Hemorrhage	Carcinoid
1948	46	8	3	Yes	0	Adrenal ca.	Carcinoid
1948	72	19	4	0	—	Pneumonia	Carcinoid
1951	66	7	3½	0	—	Cerebral hemorrhage	Carcinoid
1952	81	4	4	0	—	Arteriosclerotic gangrene of leg	Carcinoid
[illegible]	48	1	13	Yes	Local	Recurrence of tumor	Cylindroma
[illegible]	67	[illegible]	½	Yes	Local	Asphyxia because of tumor	Cylindroma

Survival of Untreated Patients.—One of the most useful yardsticks in measuring the malignancy of both the cylindroma and the carcinoid adenoma has been the analysis of what has happened to the untreated patients (Table III). Thirteen patients received either no treatment or palliative therapy in the form of repeated transbronchoscopic resections of the protruding intrabronchial tumor masses or small doses of irradiation. Two of these patients had cylindromas of the trachea; one died shortly after an attempt to restore her airway by the insertion of a long metal tube, the other is living and appa-

TABLE III. SURVIVAL RATE IN YEARS FOR 13 PATIENTS WHO RECEIVED NO DEFINITIVE TREATMENT

	AFTER ONSET OF ILLNESS			AFTER DIAGNOSIS		
	SHORTEST	LONGEST	AVERAGE	SHORTEST	LONGEST	AVERAGE
[illegible]	1	1	8.4	[illegible]	1	3.1
[illegible]		[illegible]		[illegible]	[illegible]	

[illegible]

ently no worse more than five years after biopsy. Among the patients with carcinoid adenomas, there were two whose growths were found unsuspected at autopsy and three who are now living at six months, thirteen years and fifteen years, respectively after diagnosis by bronchoscopic biopsy. The remaining six have died but survived for an average period of 4.1 years after diagnosis. One had a lymph node metastasis (Table II).

Results of Definitive Surgery.—Definitive surgery in this paper refers to the complete resection of the tumor and of any secondarily damaged pulmonary tissue when present.

The extirpation of the cylindroma is both difficult and disappointing. Two of our patients had inoperable growths. One survived a partial tracheal resection five years ago (two years after an attempt at local removal of the growth) and is alive and well seven years after diagnosis. The other returned to the hospital thirteen years after what appeared to be a complete extirpation of his tumor by pneumonectomy because of a widespread mediastinal recurrence, of which he died.

For the carcinoid adenomas the picture is different. There were no inoperable cases. Of the 43 patients who left the hospital alive after resections of their growths 38 are living and well. Two of these patients had metastases at operation, two out of five lymph nodes contained metastases in one patient, one out of sixteen in the other. Both patients are alive and well one seventeen years after operation, the other seven years after. They have been followed closely, both clinically and roentgenographically. (An analysis of the deaths has been given in Table II.)

Four patients had local resections, one through the bronchoscope, one by partial bronchial excision and two by segmental resections. They are alive and well twenty-one, four, four, and three years respectively after operation.

For 19 patients with carcinoid adenomas, at least a year passed between diagnosis and resection. Nine were operated upon before two years had expired, one before three and one before five. Four others delayed at least six years and one seven years, before coming to surgery. The remaining three patients put off resection for eleven, fourteen, and twenty-one years, respectively. Among the 38 living patients there has not been a single demonstrable metastasis nor an inoperable tumor, nor have any died of their disease. The length of survival after definitive surgery as well as from the time of diagnosis is shown in Fig. 9. There was a very significant increase in the number of patients who have had the opportunity to live five years if the time of diagnosis rather than that of resection was selected for the calculation of survival statistics. Yet as contradistinct to the adverse manner in which prolonged delays between diagnosis and resection might affect the eventual outcome of patients with bronchogenic carcinoma, such delays among persons afflicted with carcinoid adenomas have caused no material change in the percentage of survivals. The number of the patients who might have survived 5, 10, 15, 20, or 25 years have been shown at the top of this graph based on the time of diagnosis and of resection. The actual number of survivors was consistently above 86 per cent for all periods and both groups. The number of patients upon whom the statistics were calculated is too small to be of much value after fifteen years from the time of diagnosis or after ten years from the time of resection. Despite the small number of cases reported, the results are so consistent and so vastly different from those usually recorded for highly malignant neoplasms as to have considerable significance in characterizing the behavior of the carcinoid adenoma.

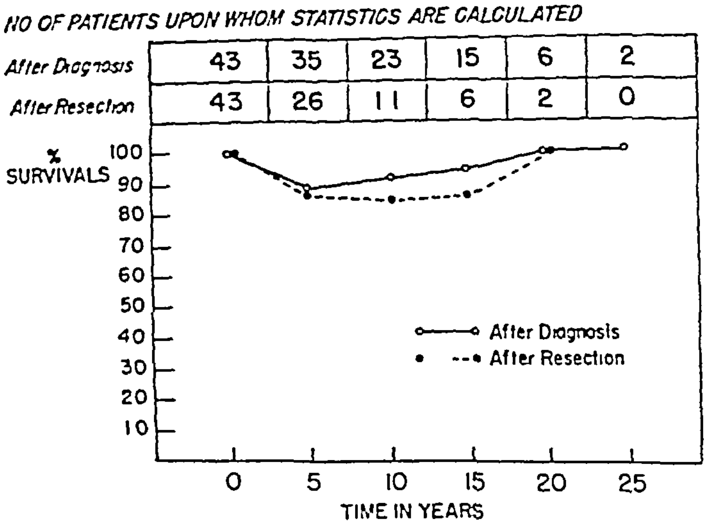


Fig. 8.—Survival rate for 43 patients receiving definitive surgery for carcinoid adenomas (all leaving the hospital alive). In the row at the top of the graph is listed the number of patients who could have survived based on the time of diagnosis; in the lower, the number based on time of operation.

CONCLUSIONS

In reviewing our small experience with the cylindroma, we have found that the histologic pattern of the tumor characterized by ample evidence of mitoses and invasive qualities has been reflected in its subsequent behavior. It is often so extensive as to be inoperable; it tends to recur and may have distant as well as local metastases. The experience of others has been similar. Although growing more slowly and metastasizing less frequently than the epidermoid carcinoma, its effect on the patient is ultimately deadly in a high proportion of cases. It remains to be proved whether intensive radiation will be helpful in controlling the cylindroma. Certainly we cannot say that radical surgery will cure it or that palliative measures are incompatible with prolonged life.

The carcinoid adenoma has always been a therapeutic problem because histologically it displays unmistakable evidence of a malignant potential but behaves clinically in a fairly innocuous fashion. Our own experience has been illustrative of this paradox. About half of the tumors available for detailed study showed local invasive qualities. Six contained demonstrable mitotic figures and one showed invasion of a lymphatic channel. [illegible] inoperable. Neither of the patients whose tumors had lymph node metastases were resected has shown evidence of recurrence. Even the metastasis found at autopsy was single and would have been surgically resectable. There have been no distant metastases and none of our patients has died of his disease despite some prolonged delays in therapy. Most of the operative procedures employed for resection of the neoplasms were as limited as the anatomy or degree of pulmonary infection would permit.

In thoracic surgery the preservation of normal lung tissue is a primary consideration. Resections which will produce excellent survival rates and still conserve the patient's pulmonary reserve are ideal. Experience with local resections is limited but encouraging.[4] Thomas[6] reported only one recurrence after four local bronchial resections and it was resectable by pneumonectomy. Several points are of importance when excisions by operations less extensive than a pneumonectomy are considered. First, diagnosis should be early by means of roentgenograms followed by bronchoscopic biopsy if possible. The fact that 11 out of our 56 tumors originated in the secondary bronchi means that when encountered early in the disease fewer tumors will be observable endoscopically. The microscopic diagnosis whether established preoperatively or when the chest is opened must be unequivocally that of carcinoid adenoma. Local excision of tumors not in this group or of those containing tissue suspected of being bronchiogenic carcinoma may be unwise. The tumor must be grossly circumscribed and noninvasive in appearance. No gross evidence of lymph node metastasis should be present. The regional nodes should be removed for microscopic study. No area of irreversible pulmonary damage secondary to the tumor should be left behind. Finally, the patient should be followed at frequent intervals so that, if recurrence appears, further surgery may be undertaken. Many of the instances of metastasizing adenomas reported in the literature were actually cylindromas or tumors of an even more malignant nature. The fact that the carcinoid adenoma can invade or metastasize by the same routes as the bronchogenic carcinoma is of less importance than the fact that it rarely does so and therefore can usually be controlled by surgery.

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DISCUSSION

DR. CHEVALIER L. JACKSON, Philadelphia, Pa.—I quite agree with one of Dr. Soutter's latter statements regarding the importance of histologic diagnosis because I feel that the crux of the confusion is in the histologic diagnosis of bronchial tumors.

A series of our cases at Temple University Hospital was reported at San Francisco in 1950 and published in *Diseases of the Chest* in 1951. We had 40 cases at that time, 36 of the carcinoid and four of the cylindroma type. Now we have 14 more cases, all carcinoid [illegible]tituting 5 per cent of the bronchial tumors seen in our clinic (900 odd since 1938) Six of these patients are dead two of them, with the cylindroma type, died of asphyxia They were inoperable in the beginning so there was no mistake in choice of therapy Two postoperative deaths were patients not operated on at Temple University Hospital One died without even having a biopsy, the patient was in for diagnosis and had one aspiration but died of subsequent hemorrhage Diagnosis was made at autopsy One patient with the carcinoid type died of carcinoma of the mediastinum and esophagus but the mediastinal metastasis probably was due to metastasis from a breast carcinoma rather than from the bronchial tumor which had been present for more than twenty years We believe that one should individualize the [illegible] in selecting treatment, and that exploration and resection should not be automatic as in the case of carcinoma But we have come to feel that about half the cases or more should be resected For in patients who are getting along well enough but are still not free of the ailment we have advised resection Dr Burnett and Dr Rosemond have done a number of resections (lobectomies and pneumonectomies) with no operative mortality We have seen no metastases in our series But we do not agree that only the "bad risks" are suitable for bronchoscopic resection because we have a number of cases in our follow up now which have been treated successfully by bronchoscopic resection alone

DR RICHARD H OVERHOLT Boston Mass —We will all agree that whenever a chest is explored for neoplastic disease the surgeon hopes for the sake of the patient that the cards will not be histologically stacked against him Dr Soutter, in his very inclusive and complete report of the experience at Massachusetts General Hospital, certainly shows that this is an entirely different type of tumor from the common bronchogenic carcinoma A number of early reports on cure rates in carcinoma undoubtedly included some of these cases and we were guilty of including some in our early reports In fact, before the meeting of this Association twenty years ago in Boston I presented two cases treated by pneumonectomy, thinking they were carcinomas Later Dr Shields Warren reviewed the histologic evidence and reclassified the two early cases as adenomas Our experience shows that of the total number of primary neoplastic tumors of the lung approximately 4 per cent have been adenomas

During the period 1931 to 1952 we have treated 51 cases of bronchial adenoma Of these 47 patients are still living and 4 are dead There were 2 operative deaths and 2 late deaths one of metastatic disease and one of carcinoma of the bladder Two cases were treated by bronchotomy, 1 by simple enucleation of the peripheral lesion 19 by lobectomy, 29 by pneumonectomy

I should like to show 2 cases the largest and then the smallest adenoma we have encountered I think Dr [illegible] will agree that in this first case it would be a little difficult to [illegible] the tumor via the bronchoscope There was a small portion projecting within the lumen but the principal mass of tumor was peribronchial as most of them are

In the x ray of the smallest lesion there was evidence of basal segmental atelectasis We expected to have to do a segmental resection or lobectomy On bronchoscopy a highly vascular tumor was found It was unwise to take bronchoscopic biopsy

At exploration and bronchotomy we found a small tumor almost entirely within the [illegible] lung [illegible] portion of the bronchial wall There had been no perma[illegible] [illegible] local excision was possible

[illegible] of the left lung was noted from x rays taken

DR [illegible] New York N Y —I should like to report briefly a rather [illegible] This was in a woman 20 years old who had symp[illegible] for a period of six months No cough or other symptoms [illegible] Several days before she was [illegible] she suddenly re[illegible] thoroughly investigated and x ra[illegible] [illegible] she had a large tumor [illegible] first reported [illegible] tumor [illegible] was treated [illegible] episode of fever and atelectasis, and bronchoscopy at that time showed that part of the eschar had dropped down into the right main bronchus and obstructed it After removal of the eschar the patient did well Now, six months after treatment started, a biopsy taken at the site of the original tumor is negative for adenoma

This patient has had numerous studies including tomography in order to rule out any evidence of extratracheal or extrabronchial neoplasm, and so far there has been no evidence of it The question I would like to raise at this time is whether this is the proper treatment for this type of case

DR ALFRED GOLDMAN, Beverly Hills, Calif—Dr Soutter was kind enough to mention a case which we had reported of bronchial adenomas with intraluminal invasion of a pulmonary vein, and I wish to report the follow up on another case (K. F, S 362 48) *

This was a woman in her thirty's, with a "mixed tumor" type of bronchial adenomas which required resection of the right lower and middle lobes We had no evidence of metastasis at the time the case was reported, and the operation was done Jan 29, 1948 Last March five years postoperatively, the patient returned with a markedly enlarged liver, although the lungs were clear An abdominal exploration was done and metastatic disease of the liver was found Biopsies of the liver were consistent with the original bronchial tumor These follow up findings are of interest because the pathologist's examination of the original tumor disclosed a marked degree of local invasion and contiguous infiltration through the bronchial wall, to a bronchial lymph node, and to the wall of the inferior pulmonary vein

This case demonstrates again the potential malignancy in bronchial adenomas for distant metastases and the necessity for observing adenomas with local invasion for distant metastases, especially in the liver, after five years or more As Dr Soutter said, this apparently does not happen in the carcinoid variety as it did in this one with a histologic diagnosis of "mixed tumor" of the adenoid cystic type

DR OSLER ABBOTT, Emory University, Ga—I wish to discuss briefly experience with three carcinoid adenomas arising on the carina Each of the three was treated by a different method The first was in a young child with known obstructive symptoms for four years A pedunculated adenoma was excised bronchoscopically in 1947, and she is now without evidence of recurrence The second was an extensive adenoma involving the right upper lobe bronchus going across to the carina It was treated in 1947 by total right pneumonectomy, removal of the tracheal wall and the contralateral medial wall of the left main stem bronchus and reconstruction by plastic closure *That patient lived for four years and died* from extensive metastatic disease of the liver The third patient had a localized process involving the carina and adjacent left main stem bronchus This adenoma was resected and repaired by dermal graft This exemplifies three different methods of handling carinal carcinoma and preventing death from suffocation Extensive reconstruction can be carried out with internally, firmly supported dermal graft to maintain the support previously provided by the cartilaginous elements in the carina

DR LAMAR SOUTTER (Closing)—In answer to Dr Seley's question, fulguration has been useful in destroying the base of tumors that have been partially removed bronchoscopically when they had no extrabronchial extension Occasional complications, including fatal hemorrhages have occurred from this treatment

In reply to Dr Jackson, it seems to me that as long as we know that a large number of these tumors go through the wall of the bronchus, it is wiser to do a bronchotomy in a good risk patient and excise the wall, than attempt to excise it transbronchoscopically Three of our patients, whose tumors had apparently been completely removed bronchoscopically, had such a severe degree of sepsis in their lungs following treatment that they needed transthoracic resection. I am not, therefore, very optimistic about that type of treatment

I am pleased to see that Dr Overholt has done some bronchotomies for carcinoid adenoma, because I feel that there is a place, although a limited one, for such operations

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*J THORACIC SURG 18 141 1949

PALLIATION OF ESOPHAGEAL OBSTRUCTION DUE TO CARCINOMA WITH A PERMANENT INTRALUMINAL TUBE

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Chicago, Ill.

RESECTION of the esophagus is feasible only in approximately one-third of the cases of carcinoma of this organ. The rate of unresectability rises with the anatomic height of the lesion because of involvement of contiguous vital structures, primarily the bronchus and the aortic arch. Extirpation of the diseased segment thus is impossible frequently, even for the sole purpose of palliation of obstruction without the expectation of cure. The esophagus, particularly in the upper region, does not lend itself readily to short-circuiting procedures to bypass the obstructed site as does the lower alimentary tract. A gastrostomy or a jejunostomy is the usual alternative to death by starvation. Either procedure leaves much to be desired from the standpoint of mechanical function as well as esthetic appeal. Gastrostomy or jejunostomy, moreover, does not affect the distressing symptom of salivary overflow resulting from obstruction. A disinclination to perform either procedure is furthered by its attendant mortality risk, which is not inconsiderable. An average of operative mortality rates for palliative gastrostomy exceeds 45.0 per cent.[2] A gastrostomy of such nature is most frequently performed subsequent to a thoracotomy when the unresectable state of the lesion first is found. The patient is thus exposed to the operative risks of both procedures.

A review of published reports indicates that esophageal resection, too, is primarily a procedure of palliation. That palliation rather than cure is the expectation is supported by a study of the results (Table I).

Survival Rate.—There is recorded one five-year survival following resection for carcinoma of the middle and upper portion of the esophagus. This is reported by Sweet as the single surviving patient of a total of 107 cases of carcinoma involving this region. As to lesions of the lower end, including those involving the cardiac end of the stomach, Table I shows that 27 five-year survivors are reported following extirpation. This includes one case of one of the authors. The [illegible] over 2,700 cases of carcinoma of the esophagus, 28 [illegible] survived for a period of five years or more.

[illegible]—[illegible] Table I shows that the over-all rate of resectability for carcinoma of the esophagus is computed at 35.0 per cent. Although

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[illegible]

a scrutiny of the reported figures does not permit an interpretation according to the location of the lesion, it seems certain that the rate of resectability for carcinoma of the middle or upper portions falls far below that for the esophagus as a whole.

TABLE I. REVIEW OF SOME RESULTS OF RESECTION FOR CARCINOMA OF ESOPHAGUS

	NUMBER OF CASES		RESECTABILITY (%)	OPERATIVE MORTALITY (%)	SURVIVORS (NO. OF YEARS) 5	4	3	2	1
Sweet[3]	*Mid and upper*	*107*	*65.0*	24.3	1				
	Lower and cardia	147		11.6	11				
Wu and Loucks[4]	Mid and upper	172	47.1	27.3	0				
	Lower and cardia			16.6	2				
Garlock and Klein[5]	Mid and upper	457 (401 operations)			0				
	Lower and cardia				11				
Resano[6]	1,000				2				
Author (S. A. M.)					1				
Humphreys and Moore[7]	162 (54 resections)		33.3	45.7	0		1	1	
Parker et al.[8]	*170 (30 resections)*		18.0	57.0	0		1		
Puestow and Cross[9]	80 (37 resections)		46.0	33.0	0				4
Strieder[10]	Mid and upper	72		55.5	0				
	Lower and cardia			12.0					
Ravitch et al.[11]					0				
Meade and Rasmussen[12]	28		32.0		0				
Santy et al.[13]	70		8.5		0				
Cook County Hospital (All services) *(1951 and 1952)*	Mid and upper	123 (42 resections)	36.2	80.7	0				
	Lower and cardia			68.7	0			1	

Resectability average 35.0 per cent; operative mortality average approximately 40.0 per cent; *28 five-year survivors out of a total of over 2,500 cases.*

Operative Mortality.—Reported rates of operative mortality range from a low of 11.6 per cent to a high of 80.7 per cent. Mortality rates for resection of the upper and mid esophagus are consistently greater than those for the lower region. The over-all mortality rate for the esophagus as a whole is computed at approximately 40.0 per cent.

In view of the foregoing it seems unreasonable to subject a patient to the hazards of esophageal resection except for the prospect of cure. When the eradication of carcinomatous tissue cannot be accomplished, and palliation alone is the aim, it would appear logical to choose a simpler procedure instead of resection and esophagogastrostomy.

A procedure which would permit food to pass through the site of carcinomatous obstruction would solve the problem of palliative alimentation. Such a method was designed and has been used in nineteen operative instances over a period of nine months. The procedure is performed at the time of thoracic exploration when it is found that the lesion cannot be extirpated or instead of a resection and esophagogastrostomy to be executed purely for the purpose of palliation.

The method consists of locally intubating the esophagus at the site of neoplastic constriction with a tube designed for this purpose (Fig. 1). The latter is passed into the lumen through an incision in the normal esophageal wall immediately above the lesion and, after having been threaded through the stenotic segment, is left in place as a permanent prosthesis. An artificial lumen is therefore constantly maintained in spite of the continued growth of the tumor.

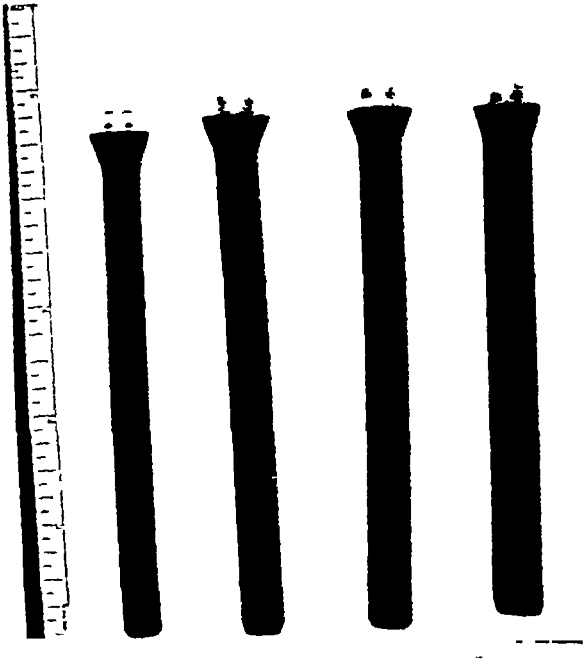


Fig. 1. Photograph of set of esophageal tubes or prostheses showing graduation in size from [illegible] to [illegible] cm. in diameter.

OPERATIVE TECHNIQUE

Lesions involving the upper two-thirds of the esophagus are approached by way of a right thoracotomy, usually through the bed of the sixth rib. The lower portion of the esophagus is exposed by means of a left thoracotomy after resecting the eighth rib.

[illegible] portion the esophagus is essentially a resident of the right hemi- [illegible] readily to surgical manipulation through this route. The azygos [illegible] to join the superior vena cava is the only structure which [illegible] It is promptly ligated and divided if it lies within [illegible] of normal esophagus approximately 2 inches above the [illegible] esophagectomy. It is unnecessary to mobilize the [illegible] by a Penrose drain for stabilization [illegible] the margin of some of its vascular supply, thus [illegible] ulcer formation. A longitudinal incision approxi- [illegible] The [illegible] is then transfixed [illegible] into the lumen. It is of importance to [illegible] that the true lumen is opened. If use of the [illegible]

An estimate of the degree of esophageal constriction is obtained by passing graded catheters These are inserted into the lumen through the esophagotomy, and are directed caudally to the area of involvement If the patient still had retained the ability to swallow liquids, the obstructed site will usually allow the passage of a No 14 Fr catheter Graduated common duct dilators are then passed to enlarge the channel to the greatest possible width Caution must be exercised not to mistake a blind recess in the tumor mass for the true lumen when *forcing through the dilating metal tip The rubber catheter is re-employed to explore* the channel for assurance The lumen usually can be made to accept a No 8 to No 10 common duct dilator A Levin tube is then passed through the compromised region, in like manner, and is directed into the stomach The prosthesis is threaded over the Levin tube and, using the latter as a guide, is pressed through the stenotic segment until its upper flared cuff rests upon the tumor mass, which prevents its further passage (Fig 2, *4, B* and *C*)

The proximal end of the Levin tube is then passed into the esophageal lumen and is directed toward the mouth, where it is retrieved by the anesthetist It then may be drawn out through the nose by means of a catheter

The esophagotomy incision is closed in two layers, mucosa and muscularis, using interrupted sutures of fine silk A periesophageal ligature of heavy silk is now placed at a level immediately above the upper, flared cuff of the intubating tube, which can be palpated through the esophageal wall This encircling ligature is drawn snugly enough so that the esophageal wall will be indented sufficiently to retain the tube and prevent its expulsion in the event of emesis, yet not so tight as to obstruct the lumen (Fig *2, D*)

It is to be emphasized that this retaining ligature is completely extraesophageal and does not pierce the wall It is felt that the wall of the esophagus should not be transfixed by *heavy, nonabsorbable sutures to secure an artificial, intraluminal device It is believed* that the intramural portion of the suture, weighted by the anchored, indwelling contrivance, would act as a drain and encourage the development of a permanent fistula

The following details in the operative technique are also referred to as *factors of* importance in the prevention of fistulas The site for the esophagotomy is chosen well above the lesion The incision is thus made in mural tissue uninvaded by carcinoma, and hence has its reparative qualities unimpaired This location also permits the prosthesis to slip *down and* away from the site of esophagotomy, thus avoiding persistent contact between the retained foreign substance and the inner surface of the healing wound The periesophageal ligature is fixed solely to indent the esophageal wall *above* the upper rim of the prosthesis, and does not embrace the latter This eliminates the possibility of strangulation of esophageal tissue between the external ligature and the unyielding tube within

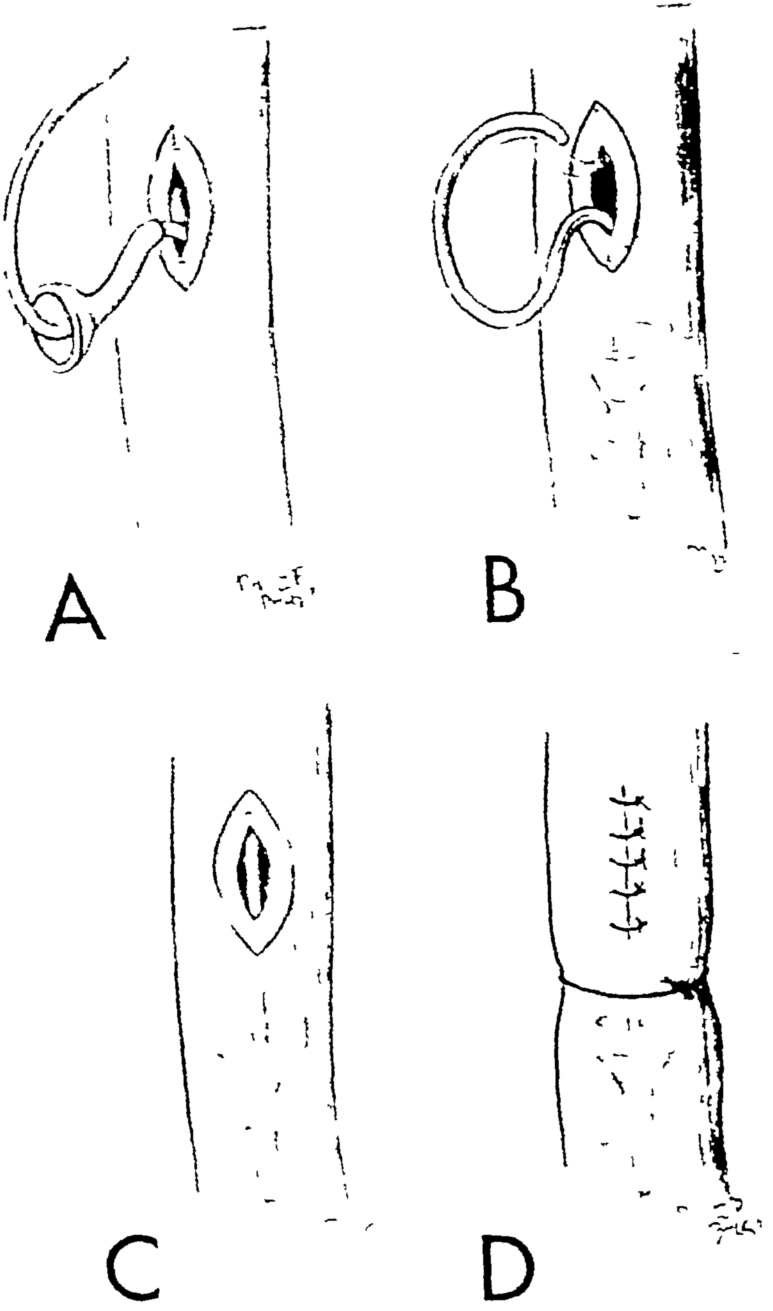
The nasogastric tube is retained until the sixth postoperative day, at which time it is withdrawn to allow the assumption of a semiliquid diet Gastric suction is maintained for the first twenty four hour period, following which the tube is utilized for the purpose of feeding

In some instances, a tumor involving the upper esophagus may project into the superior thoracic strait, thus making it impossible to gain access to a normal segment above the lesion In such a situation the operative procedure is reversed The esophagus is incised *below* the region of involvement, and the Levin tube is passed toward the mouth first The prosthesis is then guided in the oral direction and is pressed through the tumor The cuff now faces in reverse of the usual direction, but the tube is prevented from slipping to the stomach by a periesophageal ligature placed below

CASE REPORTS

The following reports have been selected as illustrative of the cases in which surgical intubation of the esophagus has been performed

CASE 1—L B (No 4), a 58 year old man was admitted to the Cook County Hospital July 20 1952, complaining of inability to swallow solid food for six weeks, and of weight loss of 0 pounds An esophagogram disclosed an obstructing lesion at the mid esophageal


A
B
C
D

[illegible]

region (Fig. 3). On August 19 an esophagoscopy was done, and a carcinoma was found 2[illegible] cm from the upper teeth. A biopsy showed this to be an "infiltrating squamous-cell carcinoma." Operation was performed on September 4.

A right thoracotomy was done through the bed of the resected sixth rib. The intention was that if the lesion were found to be resectable, and there existed the possibility of an anticipated cure, then the abdomen would be opened and the stomach, after having been freed from its anatomic attachments, would be passed into the right hemithorax where resection and esophagogastrostomy would be performed.

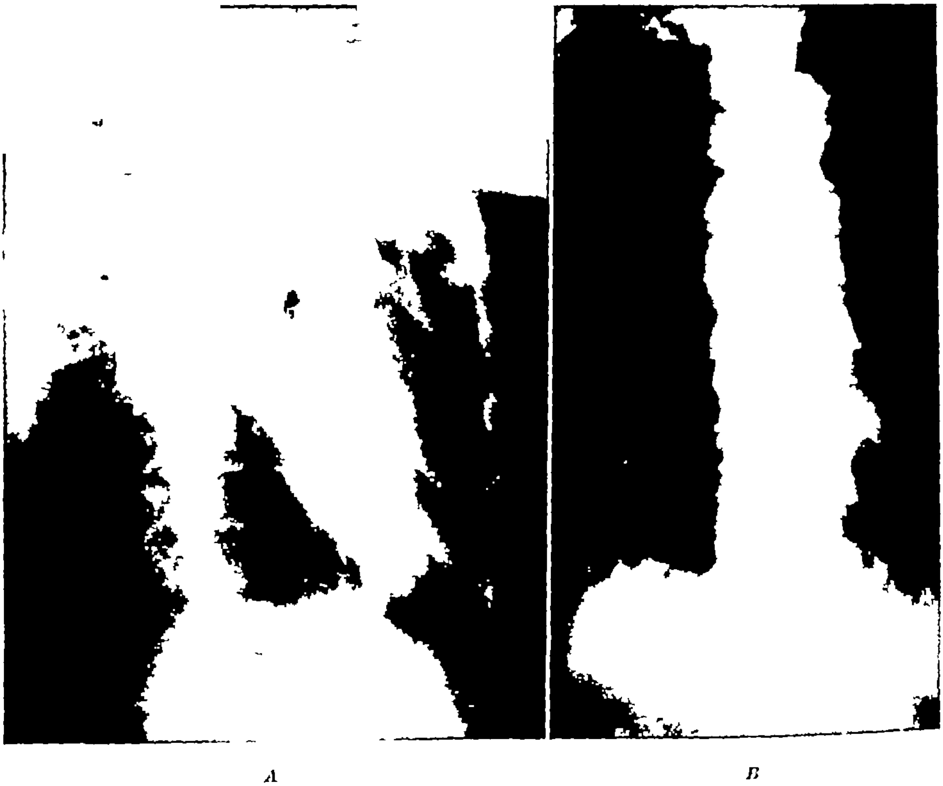


Fig. 3.—Case 1. A, Preoperative esophagogram showing complete obstruction of radiopaque mixture. B, Esophagogram taken after operative intubation demonstrating patency of the esophagus.

At operation, the carcinoma was found to involve the esophagus at the level of the azygos vein and to extend for a distance of 2 inches distally. The tumor involved the contiguous mediastinal tissues including the left bronchus and the vertebral bodies. A segment of normal appearing esophagus proximal to this site was exposed after ligating and dividing the azygos vein. A longitudinal incision 1 inch long was then made through the esophageal wall. The inferior extremity of this incision was at least 1 inch above the pathologic zone. Insertion of the plastic tube designed to remain as the permanent prosthesis was then accomplished by the *technique previously described*. The chest was closed after placing a catheter for water seal drainage of the pleural cavity.

Gastric suction was maintained for the first twenty-four hours after which the tube was utilized for gavage. It was removed six days later after which the patient swallowed a semiliquid diet without difficulty. The sense of well-being which this patient expressed upon being able to swallow once again was most gratifying.

He was discharged from the hospital on October 7 after a gain of 10 pounds in weight. He was seen two weeks later, at which time he had gained an additional 6 pounds. When last seen March 27, 1954 his weight had begun to decrease, although his ability to swallow remained unaffected. He complained of increasing weakness and beginning hoarseness.

Case 2.—H. A. (No. 8), a 50 year old man was admitted to the Cook County Hospital on Oct. 5, 1953 complaining of dysphagia and weight loss of 20 pounds in six weeks. His dysphagia had progressed rapidly so that shortly after his entrance to the hospital he experienced marked difficulty in swallowing liquids. An esophagogram showed complete obstruction at the lower portion. Esophagoscopic examination showed a large carcinoma [illegible] cm from the upper teeth. Because of dehydration, inanition and marked disturbance of electrolyte balance, it was necessary to administer multiple blood transfusions and intravenous replacement therapy. Operation was performed on October 21.

The left pleural cavity was opened through the bed of the resected eighth rib. The distal end of the esophagus was massively involved with carcinoma. The diaphragm at the hiatus was bulged upward by a solid, unyielding tumor mass which involved the infradiaphragmatic region including the cardia of the stomach. Resection was not feasible. Accordingly, a segment of normal appearing esophagus superior to the cancer bearing area was isolated and its lumen opened. After dilatation of the constriction with common duct dilators, a Levin tube was passed downward into the stomach. The tube to be permanently retained was then threaded over the Levin tube and pressed through the carcinomatous segment. Gastric content began to regurgitate through the tube. The other end of the Levin tube was then guided up the esophagus and the esophagotomy closed as previously described. A periesophageal ligature of silk was placed to prevent oral expulsion of the tube. The chest was then closed after inserting an intercostal catheter for closed drainage.

The nasogastric tube was removed six days later and the patient began to swallow unmodified food without difficulty. He was discharged from the hospital on November 10. His only complaint was gaseous eructation and "water brash," that is, the regurgitation of small mouthfuls of gastric fluid which was particularly noticeable upon reclining. The avoidance of a recumbent posture after eating greatly helped this disturbance. At the latest report, March 1, 1954, the patient was still living.

Case 3.—J. M. (No. [illegible]), a man 60 years of age was admitted to the Cook County Hospital Aug. 28, 1953 complaining of weight loss of 25 pounds and dysphagia for a period of two months. He retained the ability to swallow only liquids. An esophagogram disclosed [illegible] at the region of the middle third. An esophagoscopic examination [illegible] tumor [illegible] cm from the upper teeth, which upon biopsy proved to be "hornifying [illegible] cell [illegible] type."

A right thoracotomy was performed on September [illegible] and the pleural space opened [illegible] the sixth rib. The tumor was found to be fixed to the contiguous mediastinal [illegible]. An esophagotomy was made above this area and an esophageal tube inserted [illegible] previously described. He recovered uneventfully and started to swallow [illegible] after removal of the nasogastric tube on the sixth postoperative day. He [illegible] hospital on October [illegible].

[illegible] to the hospital on October [illegible] in a state of severe dehydration. He [illegible] esophageal tube three days prior and had been unable to [illegible] for a period of three days.

[illegible] intravenous solutions, operation was [illegible] 11. The [illegible] tube was reinserted by means of a right thoracotomy [illegible] He resumed swallowing without difficulty [illegible]

[illegible] complaining of [illegible] weakness. He [illegible] He still retained the ability [illegible] The [illegible] apparent obstruction. Although he continued to swallow a liquid diet, his condition continued to deteriorate and he died March 6, 1954. Permission for a post mortem examination could not be obtained.

RESULTS

Transthoracic intubation of the esophagus with a permanently indwelling tube to palliate the obstructive effects of carcinoma has been performed in 19 instances upon 18 patients.

One patient required reoperation (Case 3). He vomited his tube sixteen days after the first insertion and shortly thereafter became almost completely obstructed. He was readmitted to the hospital, and, following operative replacement of the tube, he resumed swallowing without difficulty.

In one case intubation could not be accomplished because of massive involvement of mediastinal lymph nodes, which precluded any type of esophageal dissection. This case has been excluded from consideration.

While a total of 19 operative cases constitutes an extremely small series and although only nine months have elapsed since the inauguration of the procedure, it is believed that a review of the results at this time is of value. In assessing the results of surgical intubation, a comparison may be made with the alternative palliative procedure of gastrostomy or jejunostomy from the standpoint of operative mortality and survival time. Consideration must be accorded the fact that whereas the latter constitutes a second operation with a mortality rate separate from that of the preceding primary thoracotomy, surgical intubation combines, as it were, exploration and palliation in a single procedure.

In the course of performing 19 transthoracic intubations of the esophagus there occurred 6 deaths which are computed as operative mortality (31.5 per cent). A fatality occurring within thirty days of the time of operation is considered as an operative death. Two of these were incurred accidentally and were not directly related to the operation. Upon his return from the operating room, oxygen was connected to the Levin tube in one case, on the mistaken assumption that the tube was for the purpose of supplying intranasal oxygen. The mistake was detected upon the appearance of massive tissue emphysema. Post-mortem examination disclosed a ruptured stomach. The second patient, a 71 year old man, slipped and fell while attempting early ambulation. He suffered a head injury and a fracture of the humerus. He died three days later.

The demise in two cases was due to cardiovascular failure. In one heart block and failure occurred twenty four hours following surgery. In the other death occurred nine days after intubation. A previous abdominal exploration disclosed an unresectable carcinoma of the stomach with massive involvement of the cardia contiguous tissues, and the distal end of the esophagus. Thoracotomy with intubation was performed ten days following the laparotomy because of complete obstruction. Although this was completely palliated he died suddenly while sitting at his bedside. A post-mortem examination gave no clue as to the cause of death. The surgical site was clean and the esophagus was intact. Death was attributed to sudden cardiovascular failure. The patient was 79 years of age.

The remaining two patients died seventeen and nineteen days, respectively, after surgery. Although clinically well and without postoperative complications, the free imbibition of an abundant liquid and semiliquid diet did not stem a gradual but steady decline in weight and strength. It is probable that the constitutional effects of the carcinoma had progressed to the critical point of no return, so that weight loss and debilitation continued even though ingestion of a diet adequate in calories was made possible.

There were twelve surviving patients who received the palliative benefits of esophageal intubation. Of these, five have succumbed to the inexorable progression of their primary disease. Their ultimate termination was due to generalized debilitation and asthenia although alimentary patency was maintained to the end. In Table II is listed their individual survival times following surgery. The mean is computed as 3.4 months.

TABLE II. SURVIVAL PERIOD OF PATIENTS SINCE DEAD

CASE NO.	DATE OF INTUBATION	DATE OF DEATH	SURVIVAL PERIOD (DAYS)
[illegible]	Aug. 26, 1953	Oct. 7, 1953	42
6	Sept. 25, 1953	March 6, 1954	162
9	Oct. [illegible] 1953	March 21, 1954	142
11	Dec. [illegible] 1953	March 15, 1954	10[illegible]
13	Dec. [illegible] 1953	March 9, 1954	69

Total number of cases [illegible] average survival period 10[illegible] days or 3.4 months

Table III shows the individual survival time of seven patients who have not as yet succumbed to the disease. Thus far the mean survival time of this group is 4.0 months. This figure has small meaning at present. By interpolation one must recognize that the ultimate survival time will far exceed 4.0 months inasmuch as these patients are still living, some having been operated upon only recently and therefore having a greater expectation of longevity. The longest period of life thus far from the time of intubation is 207 days.

TABLE III. SURVIVAL PERIOD OF PATIENTS THUS FAR STILL ALIVE

CASE NO.	DATE OF INTUBATION	SURVIVAL PERIOD (TO MARCH [illegible] 1954) (DAYS)
[illegible]	Sept. [illegible] 1953	207
[illegible]	Oct. 21, 1953	1[illegible]0
[illegible]	Nov. [illegible] 1953	1[illegible]
12	Dec. 15, 1953	116
14	Dec. 16, 1953	115
17	Jan. 16, 1954	[illegible]
18	Feb. 16, 1954	[illegible]

Total number of cases [illegible] average survival period [illegible] days or 4.0 months

In comparison, the average survival period following thoracic exploration [illegible] of the esophagus is 1.7 months as computed [illegible] gastrostomy the average period of survival [illegible] authors.

[illegible] formation and impaction passage [illegible] obstruction due to impaction [illegible]

An esophagopleural fistula, empyema, and passage of the tube into the stomach all occurred in one case. This patient had a massive carcinoma involving the cardia of the stomach and the lower end of the esophagus, with complete obstruction. At operation, great difficulty was experienced in attempting to pass catheter or metal dilator from the esophagus into the stomach through the carcinomatous region. The diaphragm was incised so that the stomach might be palpated to ensure proper guidance of the dilator as it was forced through to create a passageway from esophagus to stomach. A left empyema developed which was treated by open drainage sixteen days following intubation. He returned to the hospital thirty-five days following the original operation because of increased drainage. This was due to a fistula which later healed after tube-feeding via a Levin tube. He resumed eating, but his condition regressed and he died sixty-nine days following the operation for intubation. At post mortem examination, the intubating tube was found lying in the stomach. A roentgenogram one week prior to this showed the tube to be retained in its proper position at the cardia.

As a contributing cause for fistula formation, it is felt that the esophageal incision was made too close to the lesion so that the inferior portion of this wound was through mural tissue containing carcinoma. Care is now exercised to locate the esophagotomy farther cephalad, allowing 1 to 2 inches of normal appearing esophagus to intervene between it and the upper margin of the tumor.

One patient vomited his tube sixteen days after insertion. It was replaced by reoperation. This has been previously mentioned.

In two cases, obstruction followed impaction with food. The patient has no subjective sensation of the presence of a permanent tube and there is no interference with deglution. It is, therefore, difficult to convince him once he finds himself capable of swallowing again, to refrain from partaking of anything but a semiliquid diet. Two such patients, who remained recalcitrant to all admonitions of caution, finally obstructed their artificial passageways. Some of the impacted food could be removed via the esophagoscope. Eventual patency was achieved by digesting the remaining impaction by swallowing solutions of proteolytic enzymes such as Caroid and Papain, which are used as commercial meat tenderizing agents.

Regurgitation of small quantities of gastric content and the sensation of "heartburn" have occurred following palliation for obstruction at the cardia. These symptoms are attributable to the permanent nature of the patency between the esophagus and the stomach effected by the indwelling tube. The esophagus and the stomach are now, in effect, one single hollow viscus due to the loss of the sphincteric mechanism of the cardia. Eructation of gas may bring with it small quantities of liquid gastric content. A reclining position particularly when adopted shortly after a liquid meal, favors gravitational spill into the esophagus. The maintenance of an upright position, especially after eating has helped greatly in ameliorating these symptoms of "dyspepsia."

Post mortem examinations were conducted in five cases. Previous mention has been made of one fatality in which there appeared an empyema, healed esophageal fistula, and the presence of the tube lying free within the stomach

In the remaining four instances the surgical sites and the retained tubes were found intact and uninvolved. There did appear in one case a small mucosal erosion at a point of contact between the free terminal portion of the tube and the epithelium. This occurred in a case early in the series. At that time the tubes were more rigid in texture and the fact that they were fashioned manually by one of the authors did not lend to the artistry of their finish. No further ulcerations were found after the adoption of a tube more yielding yet incompressible in nature and commercially manufactured.*

DISCUSSION

The maintenance of a passageway through the substance of carcinoma tissue by means of a tube has been described by other authors. In 1927 Souttar[14] passed metallic tubes through malignant constrictions by means of an esophagoscope and obtained satisfactory patency in this fashion. More recently Allison[15] after condemning gastrostomy or jejunostomy as a palliative measure because of the considerable mortality, discomfort and proved inadequacy in prolonging life, has revived the use of Souttar's method. Ravitch[16] reported the operative utilization of a plastic tube in one case where resection was not feasible. Brown[17] in a similar case described the use of a metallic tube to maintain patency.

A tube of plastic material for use in the surgical treatment of carcinoma of the esophagus has been described by Berman.[18] The principle underlying utilization of this appliance is not to be confused with that of this presentation. In the technique described by Berman the tube is used to *replace* an extirpated segment of carcinoma-bearing esophagus and is substituted to bridge the gap. The operation is thus a resective procedure designed for curative purposes and ranks with esophagogastrostomy in this value. In contrast, surgical intubation as previously described is used solely for palliation when resection is not advisable or cannot be accomplished.

Trial of the technique of intubation as presented here was first prompted by the sense of frustration and helplessness in the face of inextricable lesions of the esophagus, usually in the upper and middle regions, which precluded resection even for the sole purpose of palliation. Whereas surgical intubation was first reserved for such situations, the indication for its use was broadened to include lesions which were technically resectable but where complete eradication of the neoplastic process in accordance with the basic principles of cancer surgery could not be anticipated. In such instances where the relief of obstruction rather than the prospect of cure was the consideration, the [illegible] of the palliative surgical procedure was frequently [illegible] the simpler operation, namely, intubation rather than resection. [illegible] the rapidity and uninvolved nature of the dissection, too many [illegible] would have been rejected as unsuitable candidates for a con[illegible] capable of tolerating this procedure. Indeed [illegible] the group herein reported previously had [illegible] because it was feared that [illegible] they could not withstand resection, even if feasible Instead, a gastrostomy or jejunostomy was done They were later chosen as the original candidates for thoracotomy and intubation because of a poorly functioning alimentary vent, and a progressive course of clinical deterioration

SUMMARY AND CONCLUSION

A method is described whereby palliation of obstruction due to carcinoma of the esophagus, may be achieved by the introduction of a permanently indwelling tube The tube is surgically inserted at the time of thoracic exploration when it is determined that resection of the esophagus is not feasible

It is suggested that, because of its simplicity, the method might profitably be substituted for resection and esophagogastrostomy in many instances, when the latter is performed purely for palliative purposes with no prospect of eradicating the disease process

It is felt that surgical intubation is superior to the alternate palliative procedure of gastrostomy or jejunostomy in that it may be performed at the time of the original thoracic exploration thus avoiding an additive operation that it adds to the well-being of the patient by permitting him to swallow, that it eliminates the discomfort of abdominal tube feeding, and in that it prevents the distressing symptom of salivary overflow resulting from esophageal obstruction A study of eighteen cases over a period of nine months further suggests that the survival time is greater than that accorded by gastrostomy, although it is realized that the size of the series and the brevity of the time that has elapsed do not justify definitive conclusions as to the ultimate results of this procedure

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DISCUSSION

DR. E. B. BENEDICT, Boston, Mass.—Dr. Mackler made the statement that "a gastrostomy or a jejunostomy is the sole alternative to death by starvation." I must say I cannot agree with that because we have many patients who are well palliated by swallowing a thread and using the thread as a guide to bouginage and combining that with x-ray treatment. I have three such patients under treatment at the moment and they are eating everything. I should also like to mention that his method was thought of years ago by Souttar, who used a coiled nickel or German silver wire introduced through a large esophagoscope. Souttar's method not infrequently failed owing to perforation or esophagotracheal fistula. I am convinced that x-ray treatment and bouginage offer the best palliation in inoperable carcinoma of the esophagus and I am also certain that gastrostomy is undesirable and almost never necessary.

DR. MAX G. CARTER, New Haven, Conn.—I could not agree more with any statements about the distressing effects of gastrostomy than those of Dr. Mackler. I would like to report very briefly our own experience. During the past four years we have been utilizing endoscopically such polyethylene tubes because in far the greater percentage of these patients, if they are inoperable, the inoperability can be determined before thoracotomy. So far as I know the first person to do this was Dr. Souttar in England many years ago using metal tubes. I am sure that Dr. Jackson and Dr. Benedict, having extensive experience, might comment on it further.

We fashioned tubes of polyethylene with the ends flanged. We have these ready for all endoscopies in cases with carcinoma where there is a strong suspicion that it may be nonresectable because of the advanced stage, or advanced heart disease, or extension into the trachea.

In many cases it is necessary to introduce a small No. 8 or No. 9 Jackson dilator to find the lumen. There may be no actual lumen until you dilate it a bit. Then the tube is passed over the dilator through the esophagoscope, pushing with the suction tip, and frequently it is necessary then to spread the flange with an alligator forceps.

We have some x-rays of tubes at the thoracic inlet. On the left it shows the tumor and on the right the tube is in place. It is marked at its upper end by a few turns of stainless steel wire in order to radiographically identify it.

At the other end of the esophagus there was a carcinoma of the gastric cardia which was almost totally obstructing the esophagus and was found nonresectable by virtue of its extension into the aorta. Therefore a tube was passed. We have placed them at all levels of the esophagus; the greatest difficulty is encountered in patients of advanced age with kyphosis in whom it may not be possible to get the esophagoscope down beyond the level of the aortic arch. In such cases one cannot use this method.

In summary, we have used this method during the past four years. We have attempted [illegible] patients; it has been successful in 14. In the other [illegible] been un[illegible] [illegible] and we were not able to introduce the tubes. We have had no [illegible] of esophageal perforation. In one case the tube has slipped down part way and the [illegible] another tube on top of it and it worked effectively. [illegible] radiation therapy which we are now using more extensively. [illegible] of the tumor that the tube slipped [illegible] fully by the patient.

DR. [illegible] W. [illegible]—It is quite [illegible] that the patient [illegible] [illegible] portant, as most of the lesions in this portion of the esophagus (the upper half) are radiosensitive in contrast to lesions in the lower portion of the esophagus. After a period of three or four weeks the intranasal tube can be removed. The patient will die anyway, irrespective of surgery, in an average of nine months, from dissemination of the disease and not from obstruction of the esophagus.

DR. A. L. BROWN, San Francisco, Calif.—About 1947 we published in the JOURNAL OF THORACIC SURGERY a somewhat similar procedure involving the use of a rigid tube for those individuals in whom we did not wish to do a gastrostomy. Since then we have used the same procedure in six additional cases. Our choice of cases are those in which it is determined at exploratory thoracotomy that a radical resection is not advisable. At that time we decide to put in a tube, if at all possible, so that the individual may receive irradiation therapy which, under other circumstances, we feel might shut down the esophageal lumen so tightly that we would have to use gastrostomy anyway. We have had some temporary satisfactory results with the use of the tube. One patient went a year and a half after irradiation. The tube passed about a month after insertion. The individual finally died of a cardiac ailment.

We are now using polyethelene tubes; most of our tubes extend well beyond the length of the lesion. They measure anywhere from 12 to 16 cm. in length.

We do not insert the tube through the mouth because we want to be sure, through thoracotomy, whether or not the lesion is operable. We do feel that the indwelling tube has offered these patients more comfort and relief than a gastrostomy would have offered.

DR. B. H. EVANS, Fresno, Calif.—Like Dr. Carter and Dr. Sanger, we have used an ordinary plastic vinyl tube of a type that is easily available. This is introduced directly into the esophagoscope at the time the chest is opened and the lesion found to be inoperable, being threaded through the constricted area, by bouginage if necessary, into the stomach. Then instead of bringing the proximal end out through the nostril we have made a small stab wound in the pyriform sinus and brought the tube out the lateral aspect of the neck. We do this because we feel that the tube can be better tolerated and the patients are more comfortable; they can swallow their own saliva around the tube and the salivary secretions find their way into the stomach. Supplemental feedings can be given through the tube as desired.

DR. JOHN M. SNYDER, Bethlehem, Pa.—Since I felt that there are still quite a few cases that we can be sure are inoperable beforehand, by evidence of cervical glandular metastases which can be proved and by invasion of the left stem bronchus determined by bronchoscopic examination, about three years ago I had a tube fashioned which I first used in a patient who had had difficulty after radiotherapy elsewhere. It was passed through the esophagoscope and worked well for several weeks. I thought we had an adequate retaining flange, but unfortunately in my first case the tube went on down within about three weeks. It did not cause the patient any intestinal difficulties but I became a little more discouraged than Dr. Carter, because it took about ten months to get the first tube. Perhaps I can get some more in the future.

DR. EMIL A. NACLERIO, New York, N. Y.—I want to comment briefly on seven selected patients with cancer of the esophagus who were treated during the past two years with plastic tube prosthesis applied transthoracically. In patients who are extremely poor surgical risks with complete dysphagia and/or an inoperable lesion, the use of a specially designed polyethelene tube may prove to be the optimum method of offering palliation. Earlier experiences with four patients in whom varying lengths of involved esophagus were resected and a tube was sutured in place gave poor results in that esophageal leaks occurred causing mediastinal and subcutaneous emphysema, pneumothorax, pleural effusion, atelectasis, and a low grade empyema which necessitated prolonged pleural drainage and gastrostomy. The leaks healed in two patients and they were again able to swallow despite an associated prolonged period of continued pleural disease. In another, death occurred in the fourth postoperative week from atelectasis, pneumothorax, empyema, and associated coronary disease, and the other, a patient with severe cardiac disease, died on the third postoperative day from coronary occlusion.

In view of the already mentioned complications plus the difficulties which were encountered in removing the segments of involved esophagus, which at best did not remove all of the disease, and since experience has shown that tube prosthesis brings comfort to a patient and again affords normal eating, the problem was pursued with a change in technical management.

Instead of resecting the involved segment, an incision is made into the lumen of what appears to be the normal esophagus close to the obstructing area. The constricted area itself may be enlarged by dilators or may be incised (bivalved) or a small portion of the wall may be resected. These maneuvers facilitate insertion of the tube. The tube is not rigid but is slightly flexible, which facilitates its insertion and minimizes the chances of pressure necrosis and hemorrhage. The tube is to be fixed above and below. With this approach, which is somewhat similar to the method suggested by Dr Mackler, the complications which followed when the removal of segments of the esophagus was performed have been practically eliminated.

The history is that of a [illegible]9 year old Negro woman who was unable to swallow, had a weight loss of 98 pounds and was markedly dyspneic. X-rays showed marked massive pleural effusion and lung involvement in the left chest. At operation through a left-sided thoracic incision, the lung and mediastinal organs were found to be frozen. The esophagus, which could be barely approached approximately 4 cm above the diaphragm, was incised and a tube was inserted following dilatation of the constricted area with bougies. This patient lived for eleven and one half months with maximum comfort.

The next case was that of a 51 year old man with marked kyphosis, weight loss and complete dysphagia with an obstructing lesion in the upper third. A portion of the constricted area was partially excised, thus permitting easy passage of the polyethylene tube through [illegible] esophagotomy incision. This patient lived fairly comfortably for six months and was pleased over the fact that he could again eat normally.

DR. W. E. ADAMS, Chicago, Ill.: I want to raise the question whether we should not continue to think more in terms of curative than palliative therapy. Although most of us would have a poor showing as far as long-time survival is concerned, if our attitude toward this turns toward palliative rather than curative measures, the outlook for future success in this [illegible] will be [illegible]. Dr Graham raised this point in the case of carcinoma of the lung [illegible] years ago. Although we still have much to attain in the way of [illegible] carcinoma of the lung, progress will be made if we keep curative therapy [illegible].

DR. M[illegible]: [illegible] long-time survival cases of the late Dr Phemister [illegible] which have gone between five and fifteen years [illegible] approximately [illegible] to 4 per cent of all patients explored [illegible] palliative procedures unless there is definite evidence of [illegible] only after exploration and demonstration that [illegible]

DR. S. MACKLER, Chicago: —I wish to thank the discussants for their comments and [illegible] all the questions because of the limitation of [illegible] time did not permit my acknowledging the authors [illegible] particularly Dr Souttar, who originally in 19[illegible] Dr [illegible] and Dr [illegible] This was of course [illegible] the

[illegible] tube [illegible] I feel that if [illegible]

Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty fifth Annual Meeting of the American Association for Thoracic Surgery will be held April 24, 25, and 26, 1955, in Atlantic City, New Jersey Headquarters will be at the Chalfonte Haddon Hall

Requests for Hotel Reservations

These should be mailed directly to Miss Doris Sears, Convention Manager, Chalfonte Haddon Hall, Atlantic City, New Jersey Please mention this Association, the type of accommodation desired, date and approximate hour of arrival If accommodations are desired elsewhere in Atlantic City, please communicate directly with the hotel of your choice

Thoracic Surgical Forum

By vote of the membership, the Forum is to be continued for the presentation of short papers on current thoracic research, experimental problems, anatomical studies and modified or new surgical techniques The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers or to suggest their transferral to the regular program Papers at this session will be limited sharply to ten minutes, including the showing of lantern slides or other illustrative material At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper

These papers will be published together in one issue in the JOURNAL OF THORACIC SURGERY Maximum length 3,000 words without illustrations If illustrated, an appropriate number of words must be subtracted for each cut used

Abstracts for Papers

Abstracts for the presentation of papers at the 1955 meeting, including papers before the Forum, must be received on or before Dec 15, 1954, otherwise they will not be considered by the Program Committee

Abstracts should be labeled "For Thoracic Surgical Forum," or "For Regular Program "

Five, repeat, five copies of each abstract must be sent to the Secretary of the Association, Dr Paul C Samson, 3959 Happy Valley Road, Lafayette, California They should not be sent to the Editor

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec 15, 1954, otherwise, the applications will be deferred for consideration until 1956

Applicants must be sponsored by three Active or Senior members of the Association In addition to the signatures on the application form, the sponsors must forward a *separate* letter concerning the applicant directly to Dr Lyman A Brewer, III, Chairman of the Membership Committee, 2010 Wilshire Blvd , Los Angeles 5, Calif

Completed application forms and the sponsoring letters *independently* sent by the three sponsors must be received by Dr Brewer not later than Dec 15, 1954, to be considered for action in Atlantic City

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year

The Journal of
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Original Communications

STUDIES ON CARDIAC ARREST: THE RELATIONSHIP OF HYPERCAPNIA TO VENTRICULAR FIBRILLATION

Will C. Sealy, M.D., W. Glenn Young, Jr., M.D. (by invitation), and
Jerome S. Harris, M.D. (by invitation)
Durham, N. C.

Sudden cardiac arrest constitutes one of the chief causes of death during surgery.[illegible] The precipitating factors of this accident are still obscure except in those instances of overt hypoxia, overdosage of drugs, or peripheral vasomotor collapse. The majority of cases have to be classified as due to undetermined causes. Several observers have suggested that hypercapnia may be one of the responsible factors in this group.[illegible] A series of experiments designed to study the effects of hypercapnia on the heart have been performed in our laboratory during the past several years.[illegible] A summary of the experimental findings and their clinical implications form the subject of this paper.

EXPERIMENTAL FINDINGS

Our first efforts to understand the mechanism of cardiac arrest consisted of studies of the effect of vagal stimulation on the heart during hypoxia and hypercapnia.[illegible] In these experiments 12 dogs were allowed to breathe 20 per cent carbon dioxide and 80 per cent oxygen mixtures. Stimulation of the intact right vagus nerve was carried out until "vagal escape" occurred. The duration of asystole was used as a measure of the cardiac response to vagal stimulation under the varying respiratory conditions. In all instances hypercapnia markedly increased the duration of cardiac asystole. In nine subsequent experiments employing respiratory mixtures of 10 to 40 per cent carbon dioxide, it was found that the duration of asystole varied directly with the degree of hypercapnia. Acute hypoxia, on the other hand, actually decreased the asystole produced by vagal stimulation.

[illegible]

In the experiments where prolonged hypercapnia with 30 to 40 per cent carbon dioxide was used, the dog's tolerance to severe respiratory acidosis was notable. In these animals, in spite of repeated periods of vagal stimulation, cardiac arrest was never produced. In three instances, however, ventricular fibrillation was noted when after a long period of hypercapnia the dog was allowed to breathe room air. The exact significance of this finding was not appreciated until Brown and Miller[3] made similar observations and reported in detail on this phenomenon.

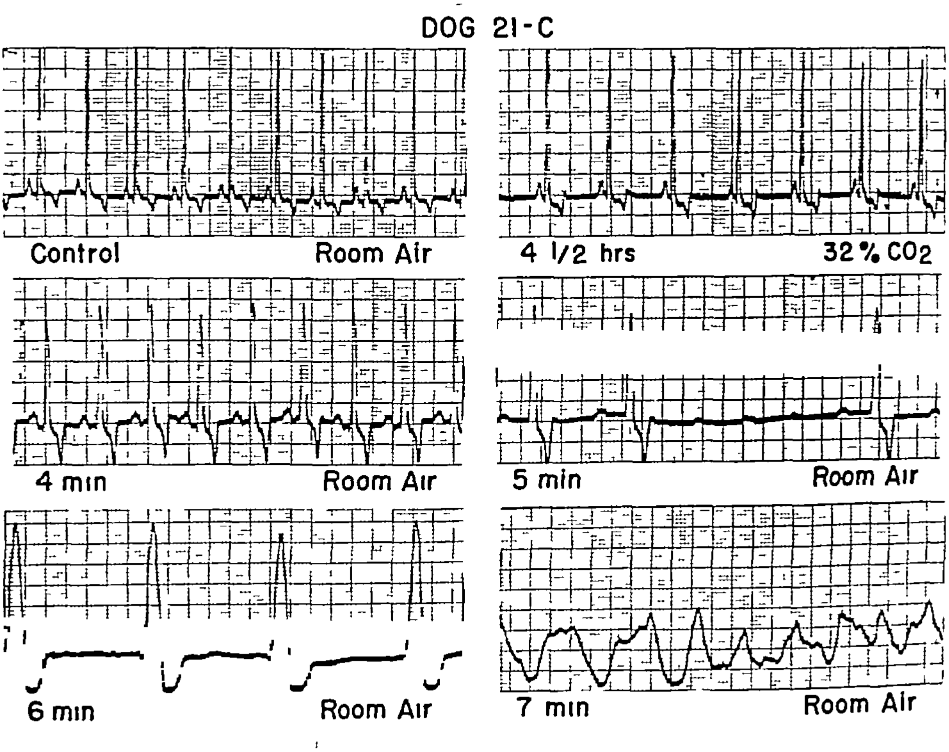

Fig. 1.—Electrocardiogram of a dog showing the development of ventricular fibrillation in the posthypercapneic period.

As shown in Fig. 1, this phenomenon of posthypercapneic ventricular fibrillation is a striking one. Significant alterations in the electrocardiogram always occurred before ventricular fibrillation. These included alterations in T waves, increase in the intraventricular conduction time, ventricular extrasystoles, and A-V dissociation.

Because of the similarity of the electrocardiographic changes of hyperkalemia with those in the posthypercapneic period another group of experiments were performed, using rats. This afforded an opportunity to study the electrolyte changes in the tissues as well as the plasma. The details of this experiment have been reported elsewhere.[20] These animals were given breathing mixtures containing 35 to 45 per cent carbon dioxide. After periods up to four and one half hours, the atmosphere in the chamber was quickly changed to room air. After two minutes the rats were killed, aortic blood was aspirated, and organs to be analyzed were removed.

The results of these experiments are shown on Chart I. The plasma potassium increased in proportion to the length of the hypercapneic period. There was also a significant increase in the level of potassium in the heart muscle but not in the skeletal muscle, liver or kidney. In several animals, electrocardiographic changes similar to those observed in the dog occurred in the posthypercapneic period.

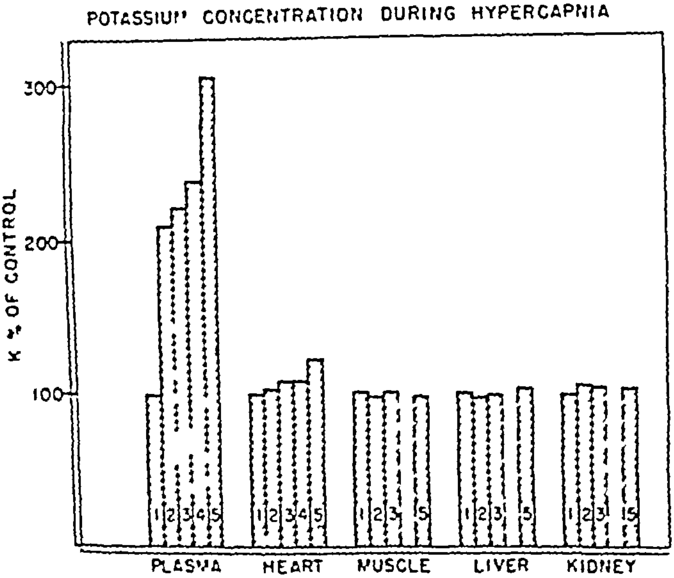

Chart I — Level of potassium in the plasma and tissues during hypercapnia. 1 Data on 31 control rats. 2 data on [illegible] animals after 1.5 to 2.4 hours of hypercapnia. 3 data on 13 rats after 2.5 to 3.4 hours. 4 data on [illegible] rats after 3.5 to 4.4 hours. 5 data on 9 rats that [illegible] in chamber after [illegible] hour.

Another series of experiments on hypercapneic dogs was then performed, so that serial determinations of the plasma potassium could be followed during hypercapnia and the posthypercapneic period and thus be more exactly correlated with the electrocardiographic changes. The dogs were anesthetized with pentobarbital sodium (30 mg. per kilogram) and given 30 to 40 per cent carbon dioxide in oxygen to breathe. Serial electrocardiogram, arterial pH, and plasma potassium determinations were obtained. After three to five hours the animals were suddenly changed from the carbon dioxide atmosphere to room air and in some instances to 100 per cent oxygen. The plasma potassium concentrations in relation to pH and hematocrit are shown in Chart II. It will be seen that there was an increase in the plasma potassium with carbon dioxide and still a further increase in the immediate posthypercapneic period. In these animals, which were carried for as long as five hours on carbon dioxide, ventricular fibrillation did not occur until the posthypercapneic period. Chart III shows the plasma potassium changes in 21 dogs. The average rise in plasma potassium on carbon dioxide breathing was from 3.91 to 6.89 meq. per liter with a further increase in the posthypercapneic period to an average of 7.86 meq. per liter. In this group 14 dogs showed significant

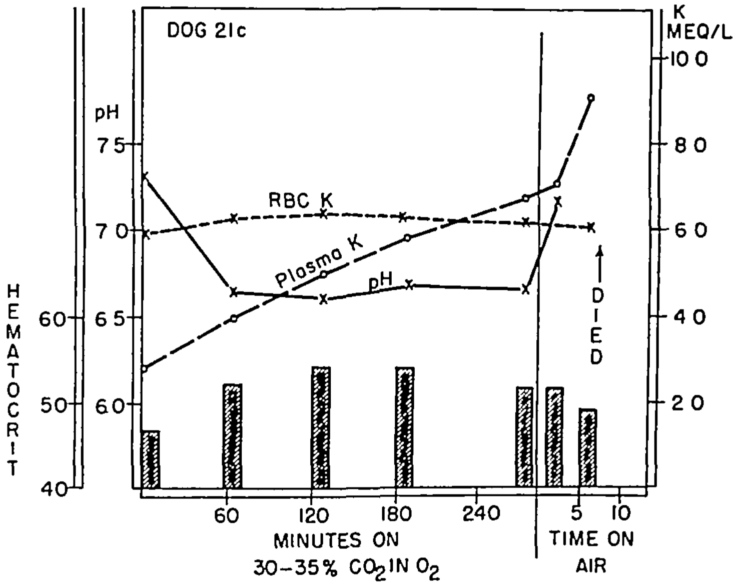

Chart II.—Changes in the pH, plasma potassium, red blood cell potassium, and hematocrit during hypercapnia and the posthypercapneic period.

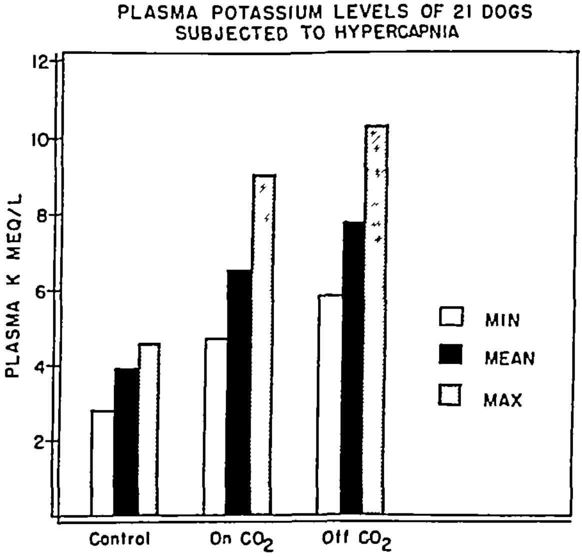

Chart III.—Comparison of the levels of plasma potassium in 21 dogs during hypercapnia and in the post hypercapneic period.

electrocardiographic changes. The average levels during hypercapnia were 7.46 meq. per liter in the dogs showing electrocardiographic changes as compared with 5.73 meq. per liter in the group without electrocardiographic changes. In the posthypercapneic period the group with normal electrocardiograms showed an average rise in potassium to 6.63 meq. per liter, while the other group increased to 8.52 meq. per liter.

A control study of the effect of hypoxia on the potassium level of the blood was done (Chart IV). In this experiment 10 per cent oxygen mixtures were given for thirty minutes, room air for fifteen minutes, and finally 10 per cent oxygen for an hour. There was a slight initial increase in the plasma potassium concentration which soon returned to normal levels.

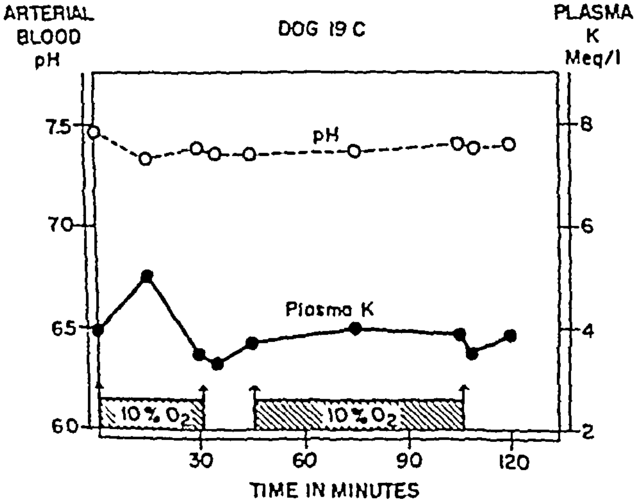

CHART IV.—Arterial blood pH and plasma potassium determinations during intermittent periods of hypoxia.

In another group of 11 experiments blood pressure and respiration tracings were made in order to determine the relation of these factors to the electrocardiogram. In most animals the blood pressure fell just after carbon dioxide breathing was started concomitant with the initial marked increase in the respiratory rate (Fig. 2). As the amplitude of respiration decreased the blood pressure rose to levels just above the control. If the animal was carried on to apnea by increasing the degree of hypercapnia the blood pressure would show a gradual fall. During this period the breathing mixtures contained 40 per cent oxygen administered by positive pressure so that [illegible] probably did not occur. When the animal was changed to room air [illegible] increase in the respiratory rate (Fig. 3). At approximately [illegible] time the blood pressure would fall to one half to two thirds of [illegible] control level followed in [illegible] time by an increase to normal levels [illegible]. [illegible] given intravenously

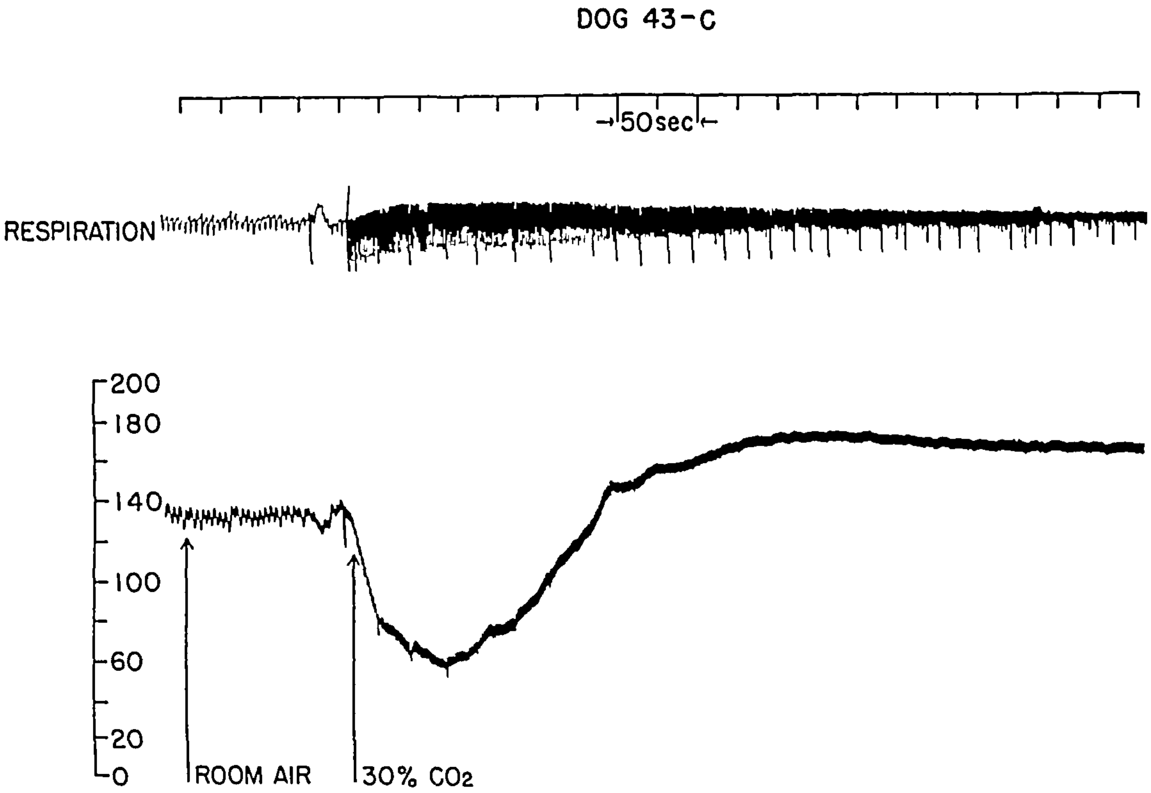

Fig 2—A tracing of the change in the blood pressure and respiration on changing from breathing room air to hypercapnia

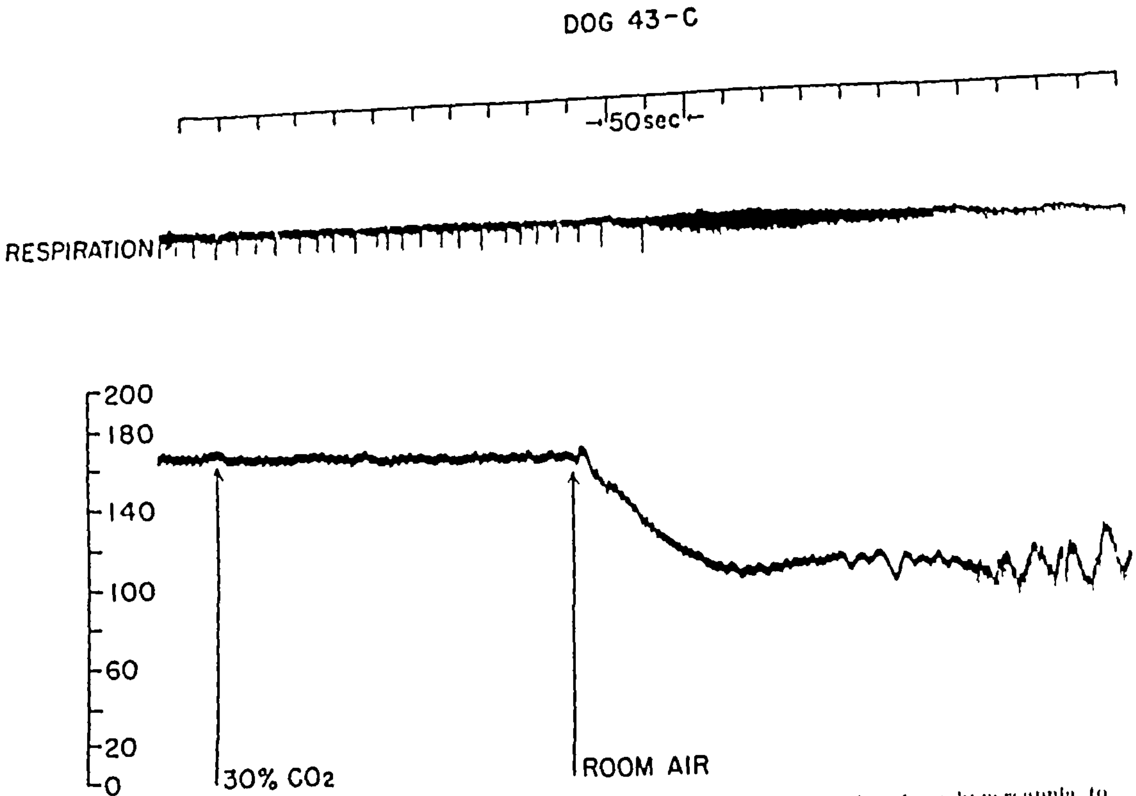

Fig. 7. A tracing of the changes in blood pressure and respiration on changing from hypercapnia to breathing room air

immediately prior to return to room air did not prevent the posthypercapneic fall in blood pressure but was followed by a further rise in plasma potassium concentration.

In order to study the relationship between potassium and hypercapnia, a series of nine experiments was performed on dogs continuously infused with 1.14 per cent potassium chloride intravenously at the rate of 1 to 2 c.c. per minute and intermittently made hypercapneic. Serial pH and plasma potassium determinations were obtained. Chart V shows the results of a typical experiment. Breathing of carbon dioxide caused a drop in the pH and a further increase in the already elevated potassium. In a dramatic fashion the effect of the posthypercapneic state on the potassium is shown. There was always a further increase in the level of the plasma potassium during this period. In one experiment it was noted that plasma potassium levels of 7.5 meq. per liter were accompanied by more severe electrocardiographic changes in the posthypercapneic period than when the same level of potassium occurred with the animal breathing carbon dioxide or stabilized on room air. The rapidity of the shifts in potassium under hypercapnia were demonstrated, for within three minutes the potassium shifted from 7.5 to 9.0 meq. per liter.

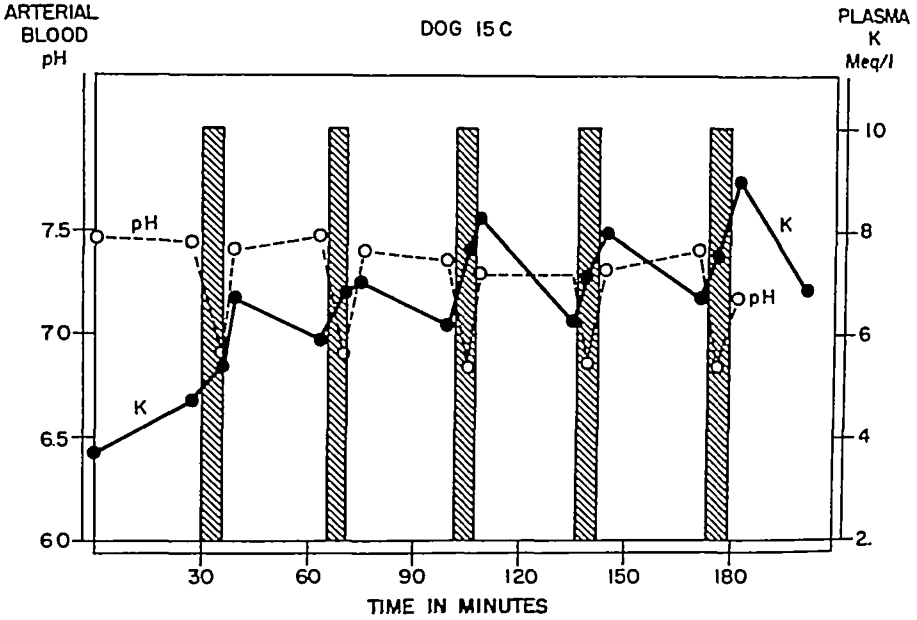

Chart V.—Effect on the arterial blood pH and plasma potassium of intermittent periods of 30 to 35 per cent carbon dioxide breathing in a dog receiving 1.14 per cent potassium chloride at the rate of 1.2 c.c. per minute by the intravenous route.

In an effort to reverse the electrocardiographic changes denoting impending fibrillation, hypertonic glucose and saline were given to nine dogs showing these changes in the posthypercapneic period. Both 20 per cent glucose and 3 per cent saline solutions were successful in reverting the electrocardiogram to normal and preventing ventricular fibrillation. Once this latter arrhythmia occurred the solutions were without effect Chart VI shows the effect of 20 per cent glucose on the posthypercapneic rise in the plasma potassium There was a marked improvement in the electrocardiogram that paralleled the fall in the plasma potassium

In another attempt to diminish the posthypercapneic rise in potassium, Benodaine,* an adrenolytic agent, was given intravenously to three dogs in doses of 1 mg per kilogram When this drug was given just prior to the return to room air, the posthypercapneic rise in potassium was prevented Benodaine caused a fall in mean arterial pressure to below 60 mm Hg No significant electrocardiographic changes accompanied this hypotension

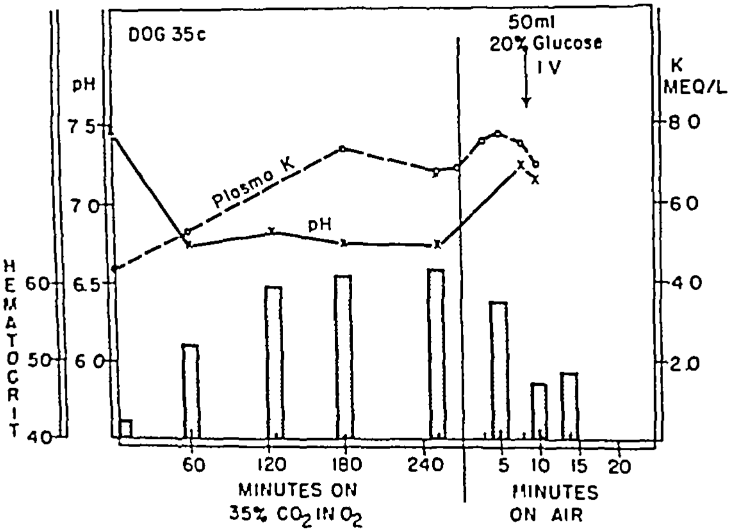

Chart VI —Changes in plasma potassium arterial pH and hematocrit during hypercapnia and in the posthypercapneic period At the onset of marked electrocardiographic changes 50 cc of 20 per cent glucose was given

The records of patients in our clinic who developed cardiac arrest were then studied Of the 36 cases studied 24 were found to have had cardiac arrest developing from unexplained reasons The remainder developed arrest from hypoxia drug poisoning or peripheral vascular collapse Ten cases of arrest in abdominal operations occurred just at the time the wound was closed or was being closed This is the time the surgeon usually demands relaxation for ease of closure This necessitated deepening the anesthesia The eleven thoracic cases developed standstill during the middle portion of the operative procedure It was considered possible that hypercapnia could have occurred in every one of these cases In one case the arrest developed just after the release of an extremity tourniquet that had been in place for forty five minutes The other two cases had the onset of arrest during the induction of anesthesia

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* [illegible]

Preliminary studies are now being made to determine if plasma potassium concentration changes of a marked degree occur during surgical operations Thus far none of the patients studied has developed severe respiratory acidosis The changes noted have been a drop in the plasma potassium to levels lower at the end of the operation than at the start It may be that these patients were hyperventilated during operation

DISCUSSION

The rapidity with which cardiac arrest occurs is the most striking aspect of this clinical phenomenon This fact has led to speculation that some reflex phenomenon was at fault [15,16,17,21] This has never been proved It is remarkable how the sympathetic and parasympathetic nerves can be stimulated with little, if any, persistent effect on the heart The results of our experiments, as well as those of others, have been remarkable in that cardiac standstill or ventricular fibrillation could not be produced by vagal stimulation alone[21] Even though hypercapnia accentuated the effect of vagal stimulation on the heart, "vagal escape" always occurred Acute hypoxia, on the other hand, diminished the effect of vagal stimulation on the heart

Hypoxia has been implicated as the principal cause of sudden cardiac arrest[7,16,17] Unquestionably hypoxia of severe degree will stop the function *of the heart and all other organs as well* In studying our patients' records it was evident that few instances of arrest were due to hypoxia In our group this was usually the result of long standing diminished circulation or obstruction to the airway

The role of hypercapnia in precipitating cardiac arrest has been suggested by several observers[4,11,12,21] This abnormal respiratory state has been found to occur frequently during operations and is the result of poor ventilation[2,16,17,18] The toxic effects of hypercapnia on the heart have been poorly understood In fact, the most outstanding observation in our experiments on hypercapnia has been the tolerance of animals for 30 to 40 per cent carbon dioxide In man, as well, clinical observations indicate that hypercapnia may be well tolerated *Brown and Miller,*[3] *in studying this respiratory state,* showed that ventricular fibrillation developed in the immediate posthypercapneic period in dogs This was the first demonstration of a serious deleterious effect of carbon dioxide on the heart

The marked similarity between the electrocardiograms of hyperpotassemia and those noted in the posthypercapneic period led us to carry out detailed studies of the plasma potassium and tissue potassium changes throughout this time both in dogs and rats[20] During hypercapnia there occurs an increase in the level of potassium, and there is a further rise in the posthypercapneic period, which may parallel the occurrence of alterations in the electrocardiogram The most obvious explanation is that these changes are due to the hyperkalemia, though the plasma potassium does not reach levels usually expected to cause ventricular fibrillation[19] It is possible that the hyperkalemia is merely a part of more profound metabolic disturbance Some of our studies suggest that the altered state caused by the hypercapnia may make the heart more sensitive to potassium Where constant infusion of potassium was given, hypercapnia for a short period of time caused marked arrhythmias of the heart at levels of 9 meq per liter, which was within the range of potassium levels in the posthypercapneic fibrillators This plasma potassium concentration did not cause similar severe arrhythmias in dogs given intravenous potassium chloride and breathing ambient air

The rise in potassium levels after cessation of hypercapnia may be due to a sudden release of Adrenalin [9, 10] This, of course, immediately leads to speculation as to the relationship of Adrenalin to ventricular fibrillation when combined with cyclopropane or chloroform Subsequent experiments have suggested that adrenolytic agents may abolish the posthypercapneic rise in the plasma potassium concentration Substances that cause a reduction in the concentration of plasma potassium also cause an improvement in the electrocardiogram The experiments where hypertonic solutions were given when electrocardiographic changes indicated impending ventricular fibrillation support this thesis

Since hyperkalemia seemed to play a role in the development of posthypercapneic cardiac arrest, other factors which might raise the plasma potassium were sought Transfusion of stored citrated blood is a possible source of potassium during operation, for as much as 2 Gm may be given in a liter of stored blood [6] The more stored blood is agitated, the more likely it is to have a high plasma potassium content The hurried administration of large quantities of blood to a patient in whom ventilation and renal excretion are impaired would seem to offer a good opportunity for the occurrence of toxic levels of plasma potassium In one of our cases cardiac arrest developed immediately after the release of a tourniquet on an extremity This suggests the possibility that a transient hyperkalemia could have occurred from the release of large quantities of potassium from ischemic muscle Some drugs such as cyclopropane may also increase the level of potassium indirectly by interference with ventilation The fact that Adrenalin increased the potassium level suggests why it may sometimes throw a failing heart into ventricular fibrillation

There are other drugs such as ether that significantly decrease the blood levels of potassium [illegible] It is a feasible assumption that this agent may actually protect the heart by reducing the levels of the plasma potassium

In our study the question has been raised whether or not the changes in the potassium level of the plasma could occur rapidly enough to bring on sudden cardiac arrest In a matter of two to three minutes the potassium level increases so markedly as shown in our experiments using carbon dioxide and continuous potassium infusion

It is obvious that the present methods of treatment of cardiac arrest are unsatisfactory and there is little promise for further improvement If our [illegible] could be interpreted as demonstrating one of the ways cardiac arrest [illegible] can this accident be prevented by utilizing these facts? First of [illegible] the prevention of hypercapnia by adequate ventilation It is of interest to note that our preliminary studies on patients undergoing surgery have shown a drop in the plasma potassium during surgery, perhaps from hyperventilation or the anesthetic agent used Brown and Miller[3] have suggested that the posthypercapneic fibrillation could be prevented by gradual, rather than a sudden, return to room air

The next method of prevention is by constant observation of the electrocardiogram, so that signs of impending ventricular fibrillation can be appreciated early enough for prevention In five of our clinical cases, where direct observation of the heart was possible, bradycardia preceded the onset of cardiac arrest Ziegler[22] noted a similar change in the electrocardiogram of cyanotic children who developed cardiac arrest while undergoing surgery In our experimental animals the electrocardiogram changed very strikingly several minutes before final ventricular fibrillation occurred This electrocardiographic change was the only sign of impending ventricular fibrillation, for there occurred no change in the blood pressure to shock levels or any fall over that expected after a short period of hypercapnia The warning electrocardiographic signs occurred early enough, so that they could be reversed with hypertonic solutions of saline or glucose

It is very tempting to implicate hypercapnia as the cause in many cases of sudden cardiac arrest In our clinical evaluation it was entirely feasible that hypercapnia could have been in part responsible for the accident in nearly two-thirds of the cases It may be possible that hypercapnia is only one of several ways the heart muscle can be damaged during surgery to the point that it is no longer able to contract forcefully Further studies on metabolic changes during surgery are needed It would seem much more likely that the causes of the so-called undetermined type of cardiac arrest lies within this category rather than from simple reflex changes, hypercapnia, hypoxia, or drug toxicity

CONCLUSION

1 Hypercapnia has been suggested as a factor in the pathogenesis of cardiac arrest

2 The critical period for the heart is the immediate posthypercapneic period

3 Studies of electrolyte metabolism in hypercapneic rats and dogs reveal a constant increase in plasma potassium concentration during this respiratory state The hyperkalemia is most marked in the posthypercapneic period, at which time serious electrocardiographic disturbances occur

4 It is suggested that changes in plasma potassium, associated perhaps with more complex metabolic disturbances in the heart, are the primary factors in the pathogenesis of posthypercapneic cardiac arrhythmias

5 The warning signs of posthypercapneic ventricular fibrillation are easily noted on the electrocardiograph before other evidence of impaired circulation occurs

6 Posthypercapneic ventricular fibrillation can be prevented by the in

travenous injection of 20 per cent glucose and 3 per cent sodium chloride when the warning electrocardiographic changes develop

7 The clinical implications of the experimental findings are discussed

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DISCUSSION

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to study the total effect of induced carbon dioxide accumulation both in the dog and in man Last year we presented evidence that the electroencephalographic pattern is changed by increasing degrees of hypercapnia in a fashion similar to that caused by ether as the depth of narcosis is increased * Ultimately all brain wave potential disappears If a dog be allowed to continue without brain wave potential caused by high levels of carbon dioxide in the blood for more than fifteen minutes, he will probably not recover Irreversible damage will have been done to his brain Both in man and animals, partial pressures of carbon dioxide in the blood sufficient to change the electroencephalographic pattern produce little change in the electrocardiogram. This is in marked contrast to the effect of hypoxia which causes electrocardiographic changes at the same time that the electroencephalographic changes occur Thus, it would appear that carbon dioxide in toxic quantities affects the brain more than the heart

In regard to the rise in blood potassium which occurs following the introduction of toxic quantities of carbon dioxide, this is a phenomenon of stress, chemical or mechanical, and may be found in numerous tissues If the kidneys be removed from a dog, there will be a rise in serum potassium if he is subjected to hypercapnia But despite the absence of the excretory mechanism, we find that the potassium returns to preoperative levels if the hypercapnia is gradually relieved This probably represents a restoration of potassium to its normal intracellular position as equilibrium is restored It is our opinion that the tendency to fibrillate following the sudden relief of hypercapnia is due in part to an imbalance between extracellular and intracellular ionic components The cause of this may be the greater speed of diffusion of the bicarbonate ion

DR N K. JENSEN, Minneapolis, Minn —Cardiac arrest actually does occur in human beings with hypercapnia We had the misfortune, while studying a group of serious respiratory cripples undergoing thoracic surgery by following their arterial pH closely, of removing two patients from the operating table with a pH of below 7, one 6 98 and the other 6 82 We had discontinued the surgery and closed rapidly because of the remarkably low pH Both patients went into cardiac arrest as they began to blow off their retained carbon dioxide These cases are of particular significance, as their arterial oxygen saturation had been closely monitored during the entire procedure, and neither had shown any anoxia The respiratory tracings clearly demonstrated, however, that the exchange was not adequate during the procedure to remove the carbon dioxide, although it was adequate with high concentrations of oxygen to keep the arterial blood level at normal oxygen saturation

DR JOHN H. GIBBON, Jr, Philadelphia, Pa —This paper concerns some fundamental and interesting changes which occur when carbon dioxide accumulates in the body Dr Allbritten reported last week to the American Surgical Association that during some twenty major thoracic operations there was no increase in the arterial carbon dioxide tension The expiratory, as well as the inspiratory phase of ventilation was assisted in all of these patients Of course what we all want to do is to avoid the changes, reported here, which occur with the inhalation of high concentrations of carbon dioxide I think we need to pay a good deal more attention to ventilation in thoracic operations

I am a little confused about one aspect of these very beautiful experiments in relation to the work of Dr Swan I was waiting for him to speak, but he did not We have been shown that breathing a high level of carbon dioxide results in an increase in the concentration of potassium in the plasma and, when the subject again breathes room air, the concentration of potassium in the plasma continues to rise for a short time even though the pH immediately begins to rise Dr Swan has reported that in hypothermic dogs, following release of caval occlusion, there was an increased concentration of potassium in the plasma But he also reported being able to defibrillate hearts by injecting potassium salts into the coronary circulation I hope Dr Swan will clarify this matter for us

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DR. HENRY SWAN II, Denver, Colo.—I have been very interested since I heard Dr. Sealy present his report on this work because I consider it extremely important. In the clinical situation during anesthesia where carbon dioxide has been accumulating and then [illegible] or another is "washed out," as the anesthetists call it, with oxygen, the exact situation which Dr. Sealy has described is set up. It is during this moment, apparently, that the potassium will rise very high and cardiac arrest may occur.

With regard to Dr. Gibbon's comment, the potassium level decreases in the serum during hyperventilation. Recently we have learned also that potassium emerges from the myocardium very rapidly during ventricular fibrillation. If one measures A-V differences in potassium between the femoral artery and the coronary sinus, one finds that in the normally beating heart there is essentially potassium balance, but during ventricular fibrillation there is a great outpouring of potassium from the myocardium as evidenced by [illegible] marked rise in the level in the blood in the coronary sinus. In retrospect this [illegible] explain why we could defibrillate the cold heart, or for that matter the warm heart, with the aid of potassium chloride and the use of electric shock, which we were not able to do without the use of the potassium. Potassium chloride, therefore, in our experience, is [illegible] of no value in preventing fibrillation, but once the heart has fibrillated and has been allowed to fibrillate for a period of time, we feel that a lot of potassium has been lost from the myocardium and for this reason potassium chloride is of aid in defibrillating these hearts.

DR. RALPH ADAMS, Brookline, Mass.—I wish to ask a few questions, hoping that some of the experts in this field will speak about the very important clinical aspects of the problem.

Six days ago I had the unhappy experience of seeing the heart of an 11 year old boy [illegible] ventricular fibrillation with cessation of effective output just as a patent ductus arteriosus was to be divided. His operative course had been satisfactory until that time. My [illegible] What does one do next when an hour and fifty minutes later he is [illegible] the heart and has not been able to get it to go out of ventricular fibrillation [illegible] effective output [illegible] momentarily? I am not an expert in this field [illegible] with ventricular fibrillation during operation. Although I have [illegible] of cardiac arrest, I believe that is a different type of emergency.

Here are [illegible] over the course of 110 minutes in trying to accomplish [illegible] maintaining cardiac massage at a rate of [illegible] to 70 com[illegible] with the patient in steep head-down position. The heart was flicked [illegible] allowed to fill with blood to dilatation and then squeezed vigorously. [illegible] with [illegible] cc. of 1 per cent procaine hydrochloride [illegible] electrical defibrillation was tried about twenty [illegible] and amperage. 10 cc. of procaine hydrochloride [illegible] into the right ventricle. [illegible] of Pronestyl hydro[illegible] A second injection of 10 cc. of 1 per cent procaine [illegible] the right ventricle.

[illegible] with [illegible] to know what to do next [illegible] What [illegible] next?

[illegible] left [illegible] The [illegible] complications typical of acute tubular nephritis, but from which I feel confident he will recover I know that others here, as well as myself, would appreciate some practical word from those men present who have had experience in this field

DR HOLMAN —Has anyone any comments or suggestions?

Question —Will someone tell us how long this can go on? Does it go on usually for ten minutes or for an hour? Is this an unusual case, or have others here had similar experiences?

DR FRANK L GERBODE, San Francisco, Calif —Actually I think this probably is a case that should go on record, because I do not know of another case of ventricular fibrillation which has been in a state of fibrillation for an hour and fifty minutes with survival Practically all the cases recorded in the literature are of relatively short duration and one either restores the sinus rhythm more or less quickly, or death occurs I think what you did was undoubtedly right, and the moral of the story is that one must persist in his efforts at resuscitation for at least an hour, the fact that you persisted for an hour and fifty minutes means that we must all profit by your experience and try harder for a longer period of time

Question —Do you think it necessary to use so many agents?

DR GERBODE —It evidently was necessary to use some of these I would use procaine amide in any difficult case of ventricular fibrillation if I could not promptly restore sinus rhythm with electrical shocks to the heart It has been shown experimentally that procaine amide is of aid in defibrillating the heart The dosage is somewhat in question, but I think 100 to 250 mg is a good dose in this situation Whether or not it was feasible in this case, or was correct to use Neo Synephrine with procaine, as Dr Adams did I think is open to question, because it has been pretty clearly shown that Adrenalin does increase the coarseness and degree of fibrillation, and perhaps Neo Synephrine does the same Anyone faced with this problem should be rather careful about using Adrenalin when ventricular fibrillation is already present Was Neo Synephrine used in the early stages of ventricular fibrillation?

DR ADAMS —That was the first thing we used

DR W GLENN YOUNG, Jr (Closing) —We appreciate the discussants' remarks I do not know how to answer Dr Adams' question except to add that there is some evidence that if the experimental animal is placed back on a high carbon dioxide mixture the electrocardiogram will revert back to normal This is brought out by B H Scribner in a paper being presented today in Atlantic City which also confirms our findings of a rise in serum potassium during hypercapnia and a further increase on return to room air If the electrocardiographic abnormalities are recognized prior to the onset of fatal arrhythmias, the administration of hypertonic glucose or saline may be indicated on the basis of our studies

We do not know whether the hyperpotassemia is the only cause for the cardiac irregularities, or whether the latter depend more directly on complex changes in cardiac muscle metabolism incident to hypercapnia In our studies on rats there was a marked difference in cardiac muscle as compared to skeletal muscle Only the cardiac muscle showed an increase in intracellular potassium during hypercapnia Our future studies will be directed toward clarifying this point

In answer to Dr Swan's remark about potassium leaving the heart during fibrillation, I wonder whether this may simply be a result of the arrhythmia, as it is well known that ischemic muscle releases potassium in large quantities, as does the anoxic liver

SOME PHYSIOLOGIC CONCEPTS OF HYPOTHERMIA AND THEIR APPLICATIONS TO CARDIAC SURGERY

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(BY INVITATION),** AND J. G. EVANS, M.D.*** (BY INVITATION)
TORONTO, ONTARIO

BECAUSE of the current interest in hypothermia it has been considered worth while to review some of the physiologic concepts and assess some of its present application to cardiac surgery. The reduction in oxygen requirements of the body produced by general hypothermia not only allows the surgeon greater leeway in dealing with the poor risk cardiac patients but permits him to interrupt the circulation for a longer period of time than would be possible at normal body temperature. Unfortunately the application of this principle to intracardiac surgery is limited at the present time by the fact that body temperatures below 24° C. (75° F.) are poorly tolerated.

Ordinary adult and laboratory animals cannot be cooled safely to a body temperature much below 20° C. (68° F.), although infant and immature animals show a greater tolerance to cold. As shown in Fig. 1, the oxygen consumption steadily declines with a fall in body temperature provided the shivering reaction is carefully controlled and the arterial oxygen saturation maintained. At 20° C. (68° F.) it is approximately 15 per cent of normal. The picture on rewarming is much the same, with a similar gradual increase in oxygen consumption as the body temperature rises.

Fig. 2 demonstrates a gradual fall in blood pressure in the initial stages of cooling and a more rapid decline below a body temperature of 24° C. (75° F.). The heart rate and cardiac output show a more progressive fall during cooling. The cardiovascular state returns to normal on rewarming. The venous pressure rises slightly during cooling. If the positive pressure artificial respiration is vigorous and over a long period of time, there is a greater rise in venous pressure.

The electrocardiographic tracings show typical changes and revert to normal on rewarming. In a continuous electroencephalographic study during cooling experiments in monkeys (Fig. 3) the wave forms diminished and there was a gradual decrease of cortical activity at 20° C. (68° F.). No wave forms

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[illegible]

suggesting cerebral anoxia were identified, and the normal tracings appeared on rewarming Behavior tests in monkeys before and after cooling were similar

In biochemical studies both Fleming and Swan demonstrated that pH of the blood can be varied within rather wide limits, depending on the rate and depth of positive pressure artificial respiration with pure oxygen[4] [5] (Fig 4) Animals appear to tolerate low body temperatures better if their pH is maintained above normal Swan also noted an interesting drop in serum potassium under the condition of hypothermia plus hyperventilation He advises the intra-atrial injection of potassium as treatment for ventricular fibrillation

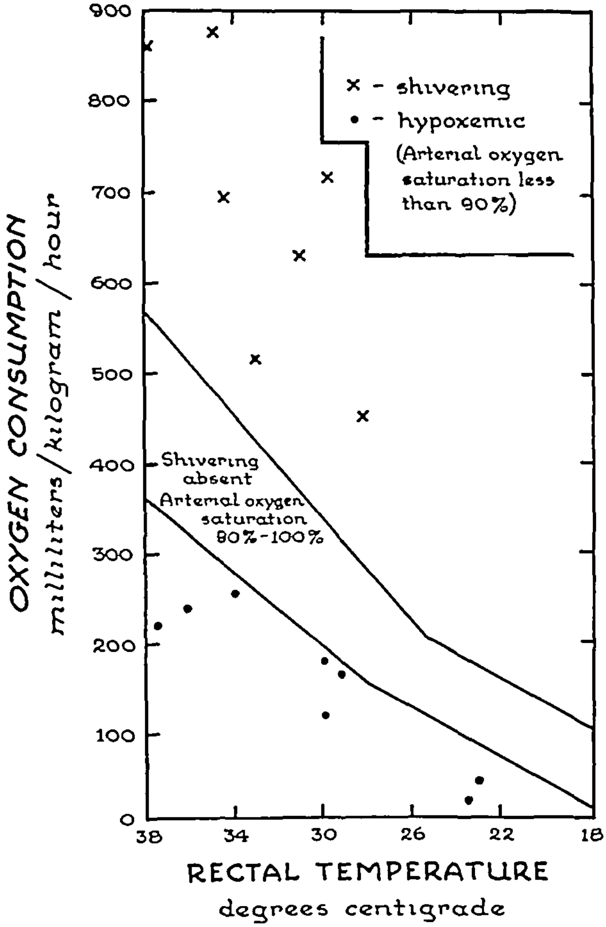
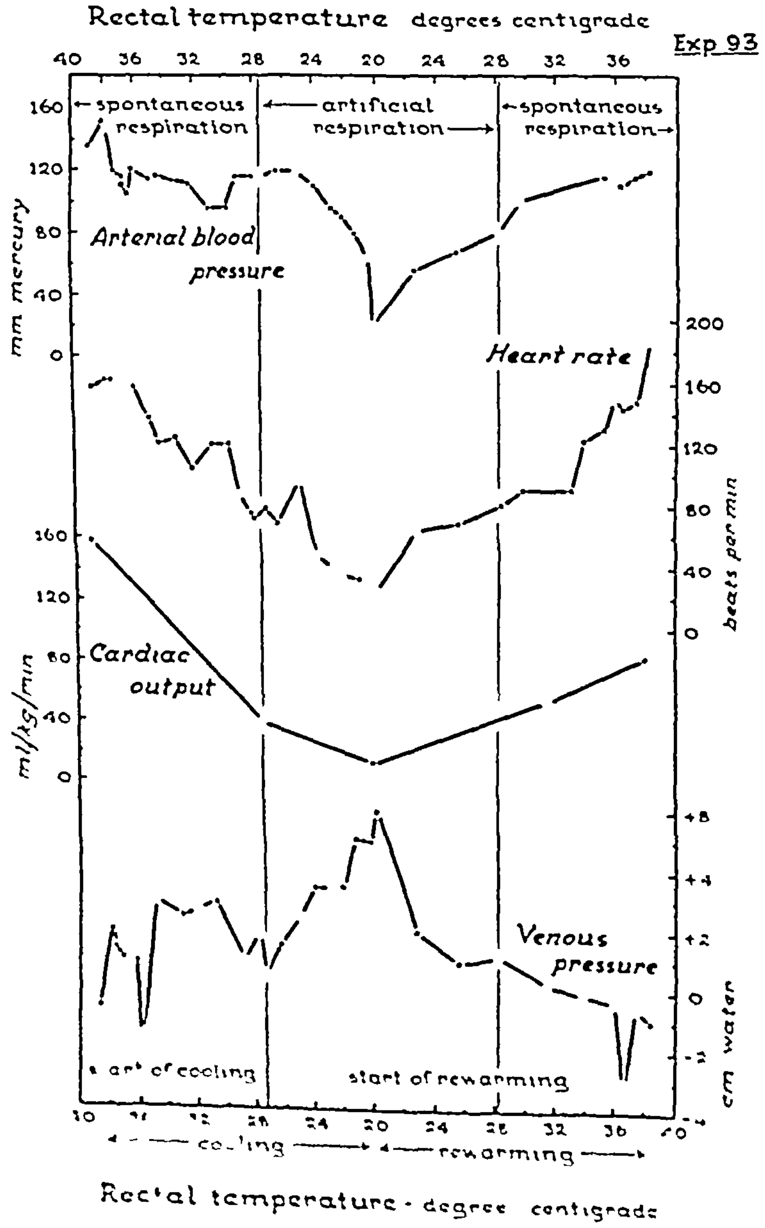


Fig 1—A fall of oxygen consumption accompanies reduction of body temperature All values which were taken under controlled conditions fell in the lined area (From Am J Physiol [3])

Since ventricular fibrillation and cardiac standstill are not uncommon complications in hypothermia, and since one or the other invariably occurs if the body temperature is reduced to too low a level, a knowledge of cardiac resuscitation is imperative To improve our ability to resuscitate animals in cardiac arrest an electrical artificial pacemaker was designed[6] which stimulates the S A node and will maintain heart rate and blood pressure in cases of cardiac standstill at low body temperature This has been combined with a defibrillator in a single resuscitation unit The electrical pacemaker has not had a satisfactory clinical trial as yet

Reports from Boerema[7] Cookson[8] Delorme,[9] Swan[10] and their co workers have demonstrated the successful application of the principle of hypothermia



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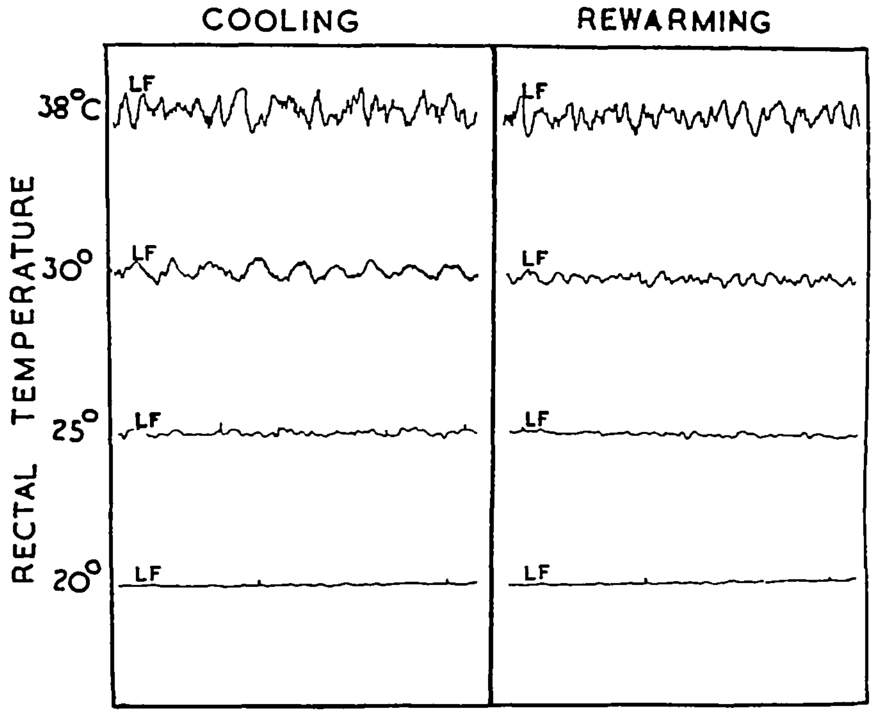

Fig 3 —Electroencephalographic changes in hypothermia. Changes noted during cooling of a monkey to a body temperature of 20° C (68 F) with rewarming There was a general depression of wave forms with no evidence of cerebral hypoxia and a return to normal on rewarming (From A M. A. Arch Surg[3])

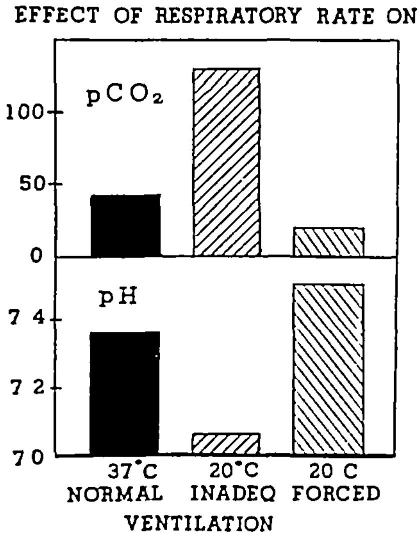

Fig 4 —A summary of changes that occur in the blood pH and CO_2 content at a body temperature of 20 C (68° F) There is a wide variation depending on the rate and depth of positive pressure ventilation with oxygen during cooling (From A M A Arch Surg[4])

to experimental intracardiac procedures. It has been demonstrated that a low body temperature increases the time during which the circulation may be interrupted. In monkeys at body temperatures of 16° C (61° F) to 19° C (66° F), we were able to exclude the heart from the circulation and open it for 15 to 24 minutes with survival in 12 of 13 experiments.

Hibernation.—The limiting factor in general hypothermia both experimentally and clinically is the danger of cardiac arrest at low body temperatures particularly below 20° C (68° F). The influence of age in this matter is interesting since young animals display a much better tolerance to low body temperature. Adolph[11] has shown that infant mammals may be cooled to temperature as low as those that are tolerated by hibernating animals 3° to 5° C (37° to 41° F). We have cooled a 10 week old puppy to 10° C (50° F) with survival so it would appear that animals and very likely human beings, lose their tolerance to low body temperatures as they mature. These facts have afforded a stimulus to investigate ways of recapturing this characteristic of the early stages of life. Evidence is available which indicates that human infants possess a similar remarkable tolerance to low body temperature which presumably is lost with age and maturity.

For several years our team has tried various biochemical agents and technical procedures in order to make cooling to low body temperatures a safe procedure and eliminate the complication of cardiac arrest. The influence of such things as balloon obstruction of the aorta irrigation of the coronary arteries and exsanguination with retransfusion has been studied. These many tedious experiments have met with only a limited improvement in our technique of cooling.

As another approach to the problem a study of hibernation has been initiated. The groundhog will not only hibernate at body temperatures as low as [illegible] C (37° F) but he can be artificially cooled to this level by using an anesthetic. At this temperature the circulation has been interrupted and heart opened from one to two hour periods on 6 groundhogs with 5 survivals. In an attempt to discover the secret of this unusual tolerance to low body temperatures biochemical studies were made of the blood both at normal body temperatures and during stages of hibernation.[2] No significant biochemical changes of the order which might explain the above phenomena were found in the blood studies of the groundhog. Thus his unusual cold tolerance has been attributed to a hibernating gland.

Studies of this gland would indicate that it is an endocrine gland of considerable size rather than a storage gland and histologically somewhat recalls the adrenal cortex. There are two large discrete segments of the gland in each axilla (Fig 5) but it is diffusely placed throughout the chest and abdomen and renders it technically impossible to remove the gland [illegible] the animal. By cooling groundhogs at various seasons of the [illegible] the results [illegible] the size of the hibernating gland a rel- [illegible] the gland and [illegible] ability to tolerate [illegible] We have been in the process of extracting this gland for the past two years, in the hope of obtaining an active principle which, when injected into nonhibernating animals and possibly human beings, will improve their cold tolerance

Present Research in Hypothermia—The present-day experimental approach to the problem of direct vision surgery of the heart is being studied with the use of (1) extracorporeal circulation, (2) hypothermia, and (3) a combination of extracorporeal circulation and hypothermia Those studying hypothermia are lowering the body temperature of animals and human beings by (a) surface cooling and by (b) extracorporeal direct cooling of the blood with or without the use of a pump

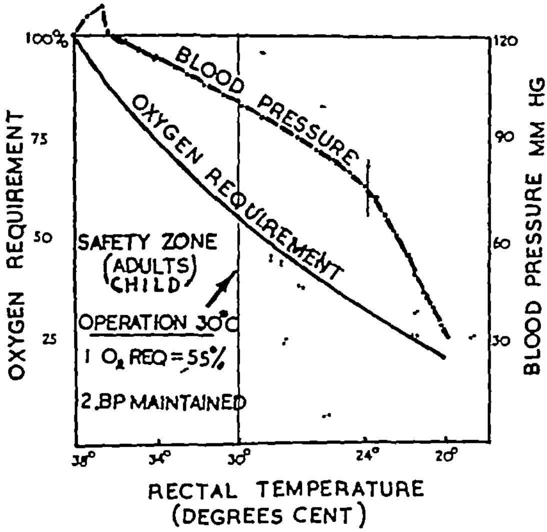

Fig 5—Hypothermia for poor-risk cardiac surgery A graphic illustration of the principles employed in using hypothermia as an adjunct. A body temperature of 30° C (86 F) under competent supervision is safe for adults and children The resulting reduction in oxygen requirements to about 55 per cent with maintained blood pressure appears to reduce the risk of surgery in poor-risk patients (From S Clin. North America August 1954)

Extracorporeal circulation studies have reached the stage of successful clinical application by Gibbon and others

Hypothermia appears to be safe when used as an adjunct to ordinary surgical techniques, but in order to improve the safety of lower body temperatures hypothermia is under study in many centers No attempt will be made to summarize all the current research that has been reported To study the mechanism of cardiac failure at low body temperatures, Lange and associates[15] have produced evidence which suggests that this is essentially a hypoxia of the myocardium Penrod[16] feels that the oxygen utilization of the heart is normal at 20° C (68° F) Edwards and associates,[17] working with R J Bing, found that the aerobic energy uptake and left ventricular work both decline, but the proportionately greater fall in ventricular work suggested a failure of mechanical efficiency of the heart in the cold state Hegnauer and Penrod[18] and Juvenelle[19] have reported interesting studies on the cardiovascular dynamics at low body temperatures The latter has noted that the myocardial oxygen consumption during ventricular fibrillation in the cold state is not greater than that of normal heart action at the same temperature

In analyzing the results of studies in hypothermia it is important to note the body temperatures used in the study Cookson Bing and Swan have made most of their observations at temperatures above 24° C (75° F) Our studies would suggest that something unfavorable happens to the animal below 24° C (75° F) Therefore it is the range of 20° C (68° F) to 24° C (75° F) that requires special attention

In combining hypothermia with extracorporeal circulation the load upon the oxygenating system is reduced Juvenelle[19] and Gollan[20] cooled animals to temperatures below the stage of cardiac irritability and arrest thus allowing a more prolonged interruption of the circulation and subsequent rewarming and survival Delorme[21] reports that extracorporeal cooling of the blood reduces the "stress" effect of hypothermia One of us (W T M) is using this combination with a biologic lung oxygenator

In the study of pure hypothermia it may be that one will not be able to control ventricular fibrillation and cardiac standstill without a clear understanding of such fundamental problems as oxygen transfer from blood to tissues and nerve conduction at low body temperatures Infant animals and hibernating animals may have a similar type of tissue metabolism which may require study

THE CLINICAL APPLICATION OF HYPOTHERMIA TO CARDIAC SURGERY

There would appear to be two main uses for hypothermia in cardiac surgery (1) to allow intracardiac exposure with interruption of the circulation and (2) as an adjunct to render certain surgical procedures upon poor risk cases more safe Twenty one cases of cooling to temperatures of 20° C (68° F) to 31° C (88° F) are reported

Hypothermia for Intracardiac Procedures—Lewis and Varco were the first to report a successful case of intracardiac surgery with hypothermia Bailey has reported a similar use of hypothermia and recently Swan has given further impetus to this work by remarkable success in the treatment of interatrial septal defects and pulmonary stenosis by direct vision techniques

The simplest method of interrupting the circulation through the heart is to clamp the two venae cavae and the azygos vein Swan points out that this can be tolerated at normal body temperature with no risk for one and one half minutes It is usually conceded that a three to four minute exclusion of the heart from the circulation is possible with an acceptable risk Judging from our oxygen consumption studies with a 50 per cent reduction in oxygen demand at a body temperature of about 28° C (82° F) one may expect a relatively safe interruption of the circulation for six to eight minutes Similarly at 20° C (68° F) with the oxygen demand reduced to ap[illegible] [illegible] per cent a period of twenty minutes should be tolerated by [illegible]

In acquired heart disease, intracardiac procedures with hypothermia would not appear to have a significant application at the present time The common lesions are usually found in adults who tolerate low body temperatures less well, and satisfactory blind intracardiac procedures are being developed The placing of homologous or plastic valves within the heart under direct vision would require too long a period of interruption of the circulation and too low a body temperature to be tolerated with any degree of safety with our present knowledge

Congenital heart disease, on the other hand, offers a wide variety of defects and a great deal of scope for the imagination in designing methods of surgical correction under direct vision In an attempt to analyze the problem of applying intracardiac procedures with hypothermia to congenital heart disease, Table I is presented

TABLE I HYPOTHERMIA FOR INTRACARDIAC PROCEDURES

DIAGNOSIS	BODY TEMPERATURE AND PERIOD OF INTERRUPTION OF CIRCULATION LIKELY REQUIRED
1 Complicated Anomalies Transposition of great vessels Tricuspid atresia Total anomalous pulmonary venous drainage Etc	20° C to 15° C (68° F to 59° F) 15 to 30 minutes
2 Interventricular Septal Defects Simple interventricular septal defects Eisenmenger's complex Tetralogy of Fallot	20° C to 15° C (68° F to 59° F) 15 to 30 minutes
3 Simple Anomalies Pulmonary stenosis Interatrial septal defects	28° C to 24° C (83° F to 75° F) 6 to 10 minutes

The patients who belong in the first group of complicated anomalies are often infants who do not survive much beyond the first year of life There are several problems which arise in the surgical correction of these defects They are usually poor surgical risks Multiple anomalies are common in association with the main defect, and accurate diagnosis is difficult One encounters a very practical problem in attempting to operate upon these patients The heart is usually so large that it occupies most of the thoracic cage and leaves little room for surgical dissection without preliminary embarrassment of the heart action Wide exposure, such as afforded by a transsternal incision, is usually required

The highest incidence of cases comes in the second group of interventricular septal defects of the three types named The proximity of the conducting mechanism of the heart presents a technical problem in any attempt to repair these defects under direct vision The majority of the simple interventricular septal defects appear to have a reasonably good prognosis without operation

In the repair of the third group of the simple anomalies (pulmonary stenosis and interatrial septal defects), reference has already been made to the reports of two successful series of cases by Swan and Lewis. Swan believes that the results are better with the direct vision approach to pulmonary stenosis than the standard Brock valvotomy. A similar comparison between the open and closed technique of repairing interatrial septal defects will also prove interesting. The time required to correct these defects can be obtained at a fairly safe body temperature level. We feel that something more should be known about the natural life history of interatrial septal defects. Our experience would suggest that young children with interatrial septal defects who develop failure are likely to have associated anomalies. So far we have been using a closed technique in adults.

Our group in Toronto has been rather conservative in applying hypothermia for intracardiac procedures. In cooperation with Dr. John D. Keith and associates of the Hospital for Sick Children three patients of the first group of complicated anomalies have been operated upon at body temperatures of 20° to 23° C. (68° to 76° F.) with one successful correction of the defect with survival. A patient with tricuspid atresia and one with pulmonary atresia were operated upon by an intracardiac approach without survival. The first patient tolerated interruption of the circulation for twenty minutes with good heart action. We were pleased with the value of hypothermia and the increase in arterial oxygen saturation associated with lower body temperature. The successful case was a total anomalous pulmonary venous drainage corrected surgically by one of us (W. T. M.) by anastomosing the common pulmonary venous trunk to the waist of the left auricle. This entailed partial obstruction of the pulmonary venous drainage for thirteen minutes and total interruption of the circulation for six minutes. The 1 year old child is remarkably improved.

No interventricular septal defects have been operated upon under direct vision. It is obvious that both this group of cases and the complicated anomalies will require a fifteen to thirty minute period of interruption of the circulation for an adequate correction of the defect. This will entail a body temperature of 20° to 15° C. (68° to 59° F.). There are not only technical difficulties as mentioned but these body temperatures are in themselves dangerous.

Two other intracardiac procedures were attempted with fatal results in our series. One was a pulmonary valvotomy under direct vision in an advanced case; the other was an error in the preoperative diagnosis.

Intracardiac surgery under hypothermia for cardiac disease will likely wait safer techniques of cooling before this method is generally accepted by all surgeons. It is a stimulating field of investigation however since some [illegible] infants and children such as the cases of transposition of great vessels [illegible] not only numerous but also hopeless. Successful correction could [illegible] relatively normal heart.

Hypothermia as an Adjunct in Poor Risk Cardiac Surgery.—Fig. 5 rep[illegible] plifies the principle employed in using hypothermia as an adjunct [illegible] operations upon poor risk patients. The body temperature of 30° C. (86° F.) is safe for both adults and children. At that temperature, judging from experimental evidence, the blood pressure should not be seriously lowered, and the oxygen requirements should be reduced to about 55 to 65 per cent of normal. Our group has operated upon sixteen patients who were very poor risks at body temperatures of 30° C. (86° F.) or slightly lower. About one-half of these were children. The indications for its use in congenital heart disease have been (a) marked cyanosis with an arterial oxygen saturation usually below 68 per cent and (b) cases where partial occlusion of the circulation may be necessary in order to complete the procedure.

In the group of acquired heart disease, hypothermia has been used in those cases where heart failure has not cleared after several weeks of hospitalization on a strict medical regimen. Most of these patients were cyanosed.

Table II lists types of cases that have been operated upon in this group at the Toronto General Hospital and the Hospital for Sick Children.

TABLE II. HYPOTHERMIA—AN ADJUNCT IN POOR RISK CARDIAC SURGERY
(Patients operated upon)

ADULTS		CHILDREN	
Mitral stenosis	7	Tetralogy of Fallot	1
Aortic regurgitation	1	Tricuspid atresia	1
Interatrial septal defects	1	Pulmonary atresia	1
Thoracotomy	1	Transposition of great vessels	3
Body temperatures	24° to 31° C. (75° to 88° F.)		
Total cases	16		
Operative deaths	4		

As indicated by the table, a mortality rate of 25 per cent appears rather high. In addition, one patient with mitral stenosis died in the postoperative period, and two of the patients with congenital heart disease died one and two months, respectively, after operation. They represent a group of cases, however, where operation at normal body temperature would have either been contraindicated, or where a much higher mortality rate than 25 per cent would have been expected.

In the congenital group the procedures carried out were: Blalock operation, pulmonary valvulotomy, and vena caval transplantation for transposition of great vessels. The arterial oxygen saturation rose from an average preoperative level of 69 per cent to an average of 78 per cent after cooling and at the commencement of the operation.

Of the 7 patients with mitral stenosis, 6 were in chronic failure and all had some peripheral and sacral edema. Five were cyanosed, and in those cases where an arterial oxygen saturation was obtained at rest preoperatively, all were below 90 per cent. Four had ascites and pleural effusion which did not clear with medical treatment. They were all emaciated and many had been in chronic failure for several years. Two patients had ceased to respond to diuretics and were in an obvious terminal state. They were treated with cortisone for ten days preoperatively. Fig. 6 shows the chest x-ray of two patients with mitral stenosis operated upon. The patients with aortic regurgitation had

[illegible]

been in chronic failure in bed for four months, and it was felt that hypothermia would allow a longer period of interruption of the aorta and reduce the danger of spinal cord injury.

In the acquired heart disease group, the profound and sustained fall in blood pressure which usually accompanies operation at normal body temperature upon such patients was not encountered. In the majority of these patients the blood pressure was maintained above 80 mm. Hg systolic, with good heart action which tolerated manipulation and showed no tendency to develop ventricular fibrillation.

One cannot conclude anything from such a small series of cases, but it is our firm impression that using hypothermia as an adjunct makes operation possible upon some of these otherwise terminal heart cases. The degree of improvement obtained in such patients with very large hearts has been remarkable. Our opinion of hypothermia as an adjunct in cardiac surgery is supported by the reports of Dogliotti,[23] Bailey,[24] and Muller.[25]

TECHNIQUE

The technique of cooling patients is not as yet standardized in our center. Both cooling blankets and cold-water baths have been used. In adults it is more practical and appeals more to the esthetic sense of the operating room staff to have them cooled with refrigerated blankets. Infants and children may be cooled either way. They are very simply cooled by being placed in a cold-water bath at 6° C. (37° F.). This produces more rapid cooling than the blanket technique. The rate of cooling also depends on their weight. Some infants have cooled at the rate of a degree centigrade every two minutes. The disadvantage in cold-water cooling in infants is the great drift of the body temperature after they have been removed from the cold-water bath, which is a result of the rapid rate of cooling. The use of cooling blankets for children provides better control of the body temperature. In all cooling procedures with an adequate circulation, the drift of body temperature after removal from the cooling medium is dependent upon three factors: (a) rate of cooling, (b) weight of the patient, and (c) temperature and humidity of the operating room.

Our present technique of cooling involves the use of preoperative administration of Phenergan, Largactil,* and Demerol. These drugs may prove to be a great aid in the development of our cooling techniques. Largactil is a ganglion blocking agent which depresses the shivering reflex and a type of sedative which acts without depressing the respiration. Phenergan and Largactil together potentiate the general anesthetic. Demerol was added for its general sedative effect. With the reduction of the shivering reflex and body temperature is allowed to fall, under the effect of sedative, provided it is in a cool environment.

Adults have been given 50 to 100 mg. each of Phenergan, Largactil and Demerol intravenously or intramuscularly over a one hour period before application of the blankets. These drugs are continued intravenously during cooling; at approximately 34° C. (93° F.) anesthesia is induced with a small amount of Pentothal. The patient is intubated with institution of positive pressure artificial respiration with oxygen. Further movement or shivering is controlled with a small amount of Pentothal or ether. The positive pressure respirations are given at about 20 per minute and moderately deep in order to blow off the carbon dioxide and to elevate slightly the pH of the blood. In order to eliminate the deleterious effect of prolonged positive pressure respirations as previously mentioned, the anesthetic is not induced until the patient has been partially cooled. Fig. 7 shows the present apparatus used in cooling. As mentioned above, our current concept of the control of respirations is a compromise based on evidence that strong positive pressure respirations with oxygen are beneficial since this elevates the pH of the blood, but when carried out for too long it increases venous pressure and predisposes to ventricular fibrillation.

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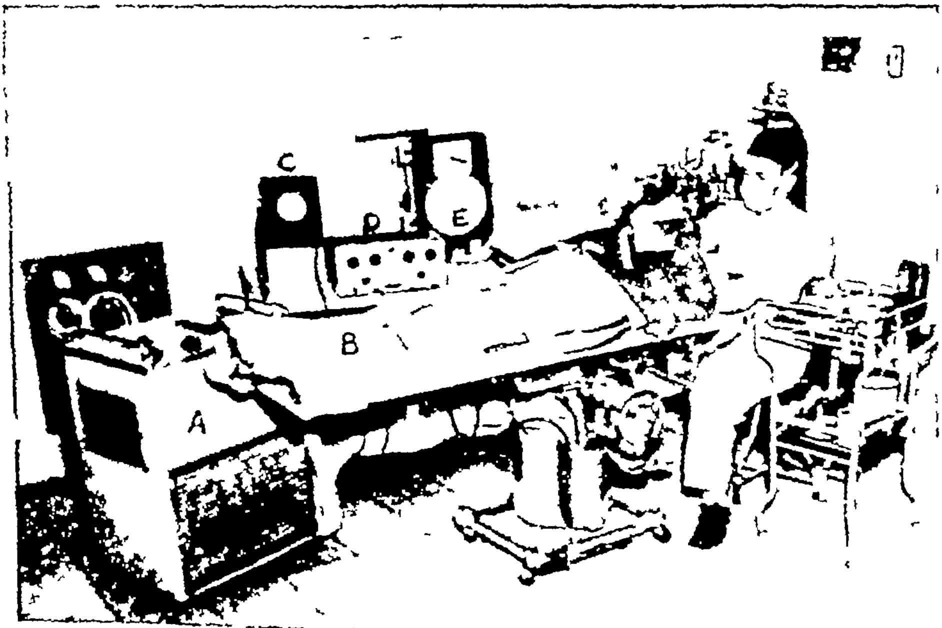
*Poulenc Limited.



[illegible]

[illegible] prolonged positive pressure respirations is [illegible] much more rapidly. These children are pre[illegible] Phenergan, Largactil and Demerol. They are [illegible] before being inserted in the cooling [illegible]

[illegible] the patient is [illegible]

athermy device[26] rewarms as rapidly as immersion in warm water On two occasions the temperature drifted to above normal There have been no other deleterious effects from the diathermy technique Our present opinion is that at temperatures above 28° C (83° F), the patient should be rewarmed by simply placing him in a bed with warm-water bottles The water bottles should be removed at a body temperature of 33° C (91° F) Patients that have been cooled to temperatures below 28° C (82° F) should be removed rapidly from this danger zone by either warm water or diathermy rewarming This should be carried out once again to a body temperature of 33° C (91° F) and the rewarming completed with the patient in warm blankets in bed These techniques will undoubtedly change with more experience

DISCUSSION

The term "hypothermia" is being used at present to describe any lowering of body temperature New terms will be required to denote different body temperature levels in order to promote clear thinking The reduction of the body temperature by a few degrees, originally suggested by McQuiston,[27] to counteract hyperpyrexia during cardiac surgery in children should be clearly differentiated from the lower body temperatures attained at present when hypothermia is used as an adjunct in poor-risk cases

The new term "artificial hibernation" used by Laborit[28] also requires clarification He has introduced the use of some very interesting drugs and is developing a new technique of anesthesia As a result of the depression of the heat regulating center produced by his "lytic cocktail," he has observed a coincident drop in body temperature of only 1° or 2° C

Hypothermia would appear to be a physiologic approach to some of our problems in cardiac surgery It is likely that with the current interest and research on this subject, the dangers of lowering body temperature below the present safe levels may be reduced

SUMMARY AND CONCLUSIONS

1 Some of the physiologic and biochemical changes produced by lowering the body temperature are discussed

2 The use of hypothermia for intracardiac surgery, at present, has a limited application Safe body temperatures do not allow a period of interruption of the circulation for long enough to correct the majority of cardiac defects

3 The use of hypothermia with a body temperature of 30° C (86° F) is advised as a useful adjunct in the cardiac surgery of poor-risk cases, both children and adults

4 Twenty one cases are discussed These patients were operated upon at temperatures ranging from 20° to 31° C (68° to 88° F)

The cardiology staffs of the Toronto General Hospital and Hospital for Sick Children Dr S M Campbell and Dr A O C Smith of the anesthetic services, Dr D R Wilson Dr B G Grapes, Dr A Sirek, Dr J W Rose, and many others cooperated in this work Dr R M Janes, Professor of Surgery, has sponsored and encouraged the work since its inception

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23. [illegible]
24. [illegible]
25. [illegible]
26. [illegible] Cardiac Surgery [illegible]
27. [illegible]
28. [illegible]
29. [illegible]

DISCUSSION

[illegible]

the performance of this operation In fact, in our own series nine patients over 16 years of age, the oldest of whom was 52 (her defect was successfully closed), have been subjected to this operation Among the nine there was only one death

The second point I would like to make concerns the ability of adult animals to tolerate profound hypothermia, body temperatures below 10° C Dr Syad Niazi, working in our laboratory, set out to make a study of the mechanism of death due to hypothermia in rats It was our expectation that these adult rats would die of ventricular fibrillation at about 15° C, as had been reported in the past, but to our amazement we found that with a careful technique of cooling and rewarming they would tolerate much lower temperatures, temperatures previously tolerated, with survival, only by hibernating animals, as Dr Bigelow has demonstrated But there has been a striking difference between the way these adult rats took to cooling and the way hibernating animals respond In contrast to hibernating animals, the adult rats go through a period of complete cardiac arrest at the low body temperatures which may last for a period of two to three hours, with recovery

I have here an electrocardiogram of a rat being cooled As the temperature falls below 15° C, the pulse becomes very slow At about 9° C cardiac standstill takes place The artificial respiration is then discontinued and the animal is cooled further to a few degrees above freezing The animal is rewarmed with hot water If there is only a thirty to forty five minute period of complete standstill, there are usually no sequelae *although some animals have had neurologic complications Over three hours of cardiac* standstill is not followed by recovery Apparently post mortem changes take place even at these low temperatures

DR HENRY SWAN, II, Denver, Colo —I wish to pay tribute to Dr Bigelow and to bring to your attention one matter of interest concerning the prevention and treatment of ventricular fibrillation in the hypothermic animal We are talking about the same temperature ranges that Dr Bigelow is discussing, that is, from 20° to 37° C Ventricular fibrillation has been the primary bugbear in our laboratory in this temperature range, especially from 25° to 20° C In the discussion of Dr Sealy's paper we are all acutely aware of the interest that is going on with regard to potassium in cardiac arrhythmias Looking on an entirely different aspect of the potassium problem, it was found by Dr Holmes and Dr Montgomery in our laboratory that *Prostigmin potentiates the flow of potassium across* the cell membrane Working with this clue, we undertook to find the effect of Prostigmin on ventricular fibrillation

In our laboratory in Colorado if you make a right ventricular incision in the cold animal you will get 100 per cent incidence of ventricular fibrillation These 23 animals served as controls All fibrillated When given 1 c c of 1 4 000 Prostigmin intravenously at about 30° C during the cooling process, ventricular fibrillation occurred in only 7 of 15 animals When Prostigmin was given to the animals by coronary perfusion (injection directly into the coronary system at the time of occlusion of the circulation) none of the 16 operated on fibrillated

As you know, Prostigmin is an anticholinesterase one would presume that if its action was by potentiating the action of acetylcholine then one could achieve the same effect by giving acetylcholine This proved to be the case Of the 5 animals, constantly given acetylcholine through the coronary system, none fibrillated We made the additional experiment to see if autogenous acetylcholine also produced this result Continuous stimulation of the distal end of the cut vagus nerve was protective in 4 of 6 animals

Coronary sinus catheterization is also a stimulus to fibrillation against which Prostigmin was protective We have had the feeling that this agent was helpful in the last 6 of the 21 patients upon whom we have performed open heart surgery

DR C P BAILEY Philadelphia, Pa —We too were stimulated by Dr Bigelow's fine basic research and after a period of animal experimentation in August, 1952, we performed what I believe was the first intracardiac operation under hypothermia It was four days before the operation performed by Dr Lewis and Dr Varco, but was much less [illegible] our patient on [illegible] during surgery. The cause of death was ventricular [illegible]. The condition for which open surgery was carried out was a large interatrial [illegible] type from a persistent ostium primum.

[illegible] with hypothermia have not been as good as those presented. We have [illegible] the circulation in more than 20 cases with a mortality of [illegible] per cent. Admittedly, we do not do open surgery when we think closed surgery will suffice. [illegible] such as transposition, extreme tetralogy, and so forth. Nevertheless, the [illegible] is a little shocking and one must consider the possible causes. Part [illegible] due to the hypothermia which depresses myocardial contraction. We feel [illegible] acquired heart disease in adults is [illegible] amenable to this modality [illegible]. Second, even in the congenital types there is a great [illegible] to the development of ventricular fibrillation which may be irreversible. Th[illegible] to the open cardiac surgery. We firmly believe that one cannot [illegible] the left side of the heart by an open technique because of the high risk of [illegible]. When a large septal defect is present, opening the right side of the heart [illegible] the same as opening the left side of the heart, and although the risk [illegible] when the left side is opened directly, there is nevertheless a residual [illegible]. I know that Dr. Gross and Dr. Lam have a way of getting air [illegible], but in our hands it has not been successful clinically. We think [illegible] should be avoided if possible.

We feel that [illegible] Potts and McQuiston have stated the situation [illegible]. Probably the best [illegible] place for hypothermia is as an adjunct to the [illegible] of congenital heart disease. Preferably it should not be a very severe [illegible]. In fact, Potts has expressed the view that the more important element [illegible] the avoidance of hypercapnia during and after surgery rather than the [illegible].

DR. EDWARD E. [illegible] (Chicago, Ill.)—Dr. Bigelow mentioned that hyperventilation [illegible] adverse effects leading to ventricular fibrillation during hypothermia [illegible] also produce deleterious effects [illegible]. The [illegible] of prolonged positive pressure breathing [illegible] and Maloney and Whittenberger in 1947. More recent work by Mor[illegible] [illegible] that the positive [illegible] rapid fall of pressure [illegible] In [illegible] half [illegible] ventilation [illegible]

[illegible]

no surgery being performed Many of the findings we have accumulated during this time do not completely agree with some of the basic data which have been reported and which *form the basis for certain specific recommendations as to management of patients* I think that clarification has to be made because if one has an animal or a patient with an open thoracotomy and a cardiac surgical procedure, there are certainly introduced additional factors beyond those resulting from hypothermia Caval occlusion has been a part of some of the procedures, which in itself produces certain changes

We have operated on eight patients under hypothermia about half of them brought down to 23° C and half to about 31° C The mortality was about 30 per cent The second point I wish to emphasize is that I do not think hypothermia played a major role in the mortality, since the patients who did not survive were those who had large septum primum, transposition, or a condition of a serious nature

Last week we had a sad experience with an adult with an arterial saturation of 18 per cent from a tetralogy of the infundibular type We had planned to keep him at 30° C but he drifted unpredictably down to 25° C At that point he fibrillated, as we were opening the chest We tried electric shock several times and even potassium chloride, with no success In addition, we performed cardiac massage for a considerable time I think Dr Ralph Adams is quite right in feeling that the fibrillation problem is not yet a simple one

In the older adult group with abdominal aortic aneurysms, I have preferred to try *the Laborit drug hibernation technique I have used it on three old high risk patients* with satisfactory results I was afraid to use surface hypothermia in that group, although I understand some surgeons have done so

DR W G BIGELOW (Closing)—I should like to thank the discussants very much Dr Lewis made a remark about cooling a rat down to very low temperatures with cessation of cardiac function for long periods, and rewarming This is a function of the laboratory animal which he has used He is using an animal which is small and can be rapidly cooled and rapidly rewarmed This experiment is difficult to duplicate on an animal of larger body mass, because its body temperature cannot be lowered rapidly by ordinary surface cooling techniques In the time that it takes to get them into the low temperature zone, anoxia due to cessation of cardiac function would intervene and put the heart in a state where it could not be resuscitated It is an interesting experiment This is possible in larger animals such as the groundhog One may cool them to 3° C and interrupt their circulation with the heart open for one to two hours, with survival In these animals, however, the heart continues to function, and circulation is maintained

Dr Swan's use of Prostigmin is very interesting We have been rather parallel in our thinking both regarding the effect of hyperventilation and now the significance of the acetylcholine mechanism which has caught our interest I agree with Dr Bailey that the present most useful place for hypothermia is as an adjunct I might make a comment on Dr Deterling s problem of drifting of the body temperature after removal from the cooling medium There are two methods by which you may cool an individual, with blankets or with a cold water bath In adults we like to use blankets and, if the blanket is good and cold with the help of ice bags one can cool patients fairly rapidly It is somewhat more esthetic to the operating room staff to have the adults in blankets However, in children both blankets and cold water baths are acceptable The advantage of cold water is that it cools them more quickly The disadvantage is that they drift more and it is difficult to control the temperature once you take them out of the bath The use of blankets in children is acceptable because it gives a more constant temperature without the marked tendency to drift

THE SURGERY OF INFUNDIBULAR PULMONIC STENOSIS WITH INTACT VENTRICULAR SEPTUM (A TYPE OF PURE PULMONIC STENOSIS)

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Philadelphia, Pa.

PULMONIC stenosis in the presence of an intact ventricular septum is perhaps the most gratifying and satisfactory type of intracardiac lesion with which the present day cardiovascular surgeon must deal. For this state of affairs the profession is indebted to the initial efforts of Doyen[1] in 1913 and more recently, to Sellors and Brock who were instrumental in the development of the direct surgical approach for the relief of this condition. The past five years have witnessed widespread interest in the problem of structural obstructions within the outflow tract of the right ventricle.

Several investigators[4] have reported that pulmonic stenosis is usually valvular in type when the interventricular septum is intact, whereas an infundibular type of stenosis is common in the presence of an interventricular septal defect. The purpose of this communication is to present the findings in six patients with pulmonic stenosis of the infundibular type but in which the ventricular septum was intact. In five patients the infundibular location of the stenosis was suggested preoperatively by roentgenographic means and by cardiac catheterization; in all six patients the diagnosis was confirmed at surgery.

For the sake of simplicity, hereafter when pulmonic stenosis (valvular, infundibular or combined) occurs in the presence of an intact ventricular and atrial septum it will be referred to as pure pulmonic stenosis. If pulmonic stenosis occurs with an intact ventricular septum but with an interatrial communication (patent foramen ovale or true atrial septal defect) it will be referred to as the trilogy of Fallot.[5]

The signs and symptoms common to these two entities, that is, pure pulmonic stenosis and the trilogy of Fallot, are related to an increased pressure in the right ventricle and often to a decreased pulmonary blood flow. Increased pressure in the right ventricle occurs in association with pulmonic stenosis with or without an intact ventricular septum and the pressure in the

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[illegible]

pulmonary artery is always lower than that in the right ventricle. Increased right ventricular pressure may also occur in any anomaly characterized by a large left-to-right shunt or in idiopathic pulmonary hypertension but in these conditions the pressure in the pulmonary artery is also elevated.

Inadequate pulmonary blood flow may result from failure of one or both venae cavae to enter the right atrium or from anatomic obstruction at different levels in the right side of the heart and/or in the pulmonary arterial tree, for example, tricuspid atresia, Ebstein's disease, pulmonary infundibular or valvular stenosis, pulmonary atresia, or in severe pulmonary hypertension.

There is no known natural mechanism to relieve the high pressure in the right ventricle, although surgical procedures may afford some relief for the elevated pressure in some types of malformation. Furthermore, although persistent patency of the ductus arteriosus and the establishment of a collateral circulation may partially compensate for an inadequate pulmonary blood flow, the former usually affords only temporary and often an incomplete blood supply, and collateral circulation is often insufficient to maintain an adequate pulmonary blood flow. The establishment of an adequate pulmonary blood flow has been made possible in a number of these conditions by different surgical procedures, such as systemic-pulmonary artery anastomosis,[10, 11] valvotomy,[12, 13] and infundibular resection.[14-17] In others no surgical amelioration has been feasible to date.

Frequency.—Pulmonic stenosis as part of the tetralogy of Fallot is one of the most frequent malformations of the heart[1] and is certainly the commonest lesion in the cyanotic group of congenital heart diseases. Pure pulmonic stenosis and trilogy of Fallot have until recently been considered very rare malformations of the heart. In Fallot's[9] series of 40 cases of cyanotic congenital heart disease, 7 were examples of the trilogy, that is pulmonic stenosis with an intact ventricular septum, interatrial communication, and right ventricular hypertrophy. In Abbott's[18] series of autopsies there were 25 instances of pulmonic stenosis with an intact ventricular septum in 1,000 cases of congenital heart diseases; of these, 16 had a patent foramen ovale, and in the remainder the interatrial septum was anatomically closed. In Escalle's[19] series there were 16 instances of pure pulmonic stenosis as compared to 21 of the trilogy of Fallot. Sir Arthur Keith[20] in 1909 was probably the first author to call attention to the occurrence of pulmonic infundibular stenosis with an intact ventricular septum. In 1949, Greene and associates,[21] reviewing the literature dealing with pulmonic stenosis with an intact ventricular septum, found 17 instances of infundibular stenosis in a total of 68 cases; in 5 of these there was also an associated valvular stenosis. Selzer and co-workers,[22] in a study including 23 selected cases of pure pulmonic stenosis, found 5 instances of myocardial infundibular stenosis, 2 of membranous infundibular stenosis, and 15 of valvular stenosis; of 29 cases of the trilogy of Fallot, there was only one instance of 'subvalvular membrane,' the stenosis being valvular in the remaining 28 patients. In a series of 25 cases of pulmonic stenosis with intact ventricular septa operated on by the authors, there were 6 instances in which the stenosis was infundibular or combined valvular and infundibular

Diagnosis of Pulmonic Stenosis With Intact Ventricular Septum.—An increasing amount of clinical,[illegible] electrocardiographic,[illegible] roentgenologic,[illegible] angiocardiographic,[illegible] physiologic,[illegible] surgical[illegible] and anatomic[illegible] data concerning this malformation have been accumulated in recent years. The correlation of these data has made possible a rather accurate clinical diagnosis of pulmonic stenosis with intact ventricular septum. However, to date a *definitive* diagnosis of this malformation can be made only by interpreting the results of cardiac catheterization.

The symptoms, signs and physiopathologic findings in this entity may vary somewhat with the degree, site and type of stenosis as well as with the presence or absence of an interatrial communication. The usual manifestations in infants and children with pulmonic stenosis with an intact ventricular and atrial septum will be presented. The changes brought about by the presence of an associated interatrial communication and the differential diagnosis of infundibular and valvular stenosis will be discussed.

Pure Pulmonic Stenosis.—Dyspnea, usually noted on exertion and out of proportion to the degree of cyanosis, is the most frequent symptom. Easy fatigability is noted in association with dyspnea. Inadequate gain in weight is a common complaint. Squatting, although not as frequent as in tetralogy of Fallot, may occur.

Physical examination usually reveals no cyanosis; when present it seems to be due to severe peripheral venous unsaturation (peripheral cyanosis) and not to a venous-arterial shunt, as the arterial oxygen saturation is always normal. The chest may be symmetrical or may show varying degrees of precordial bulge as a result of right ventricular hypertrophy, but cardiac enlargement is usually not detected clinically. Auscultation reveals a systolic murmur, often accompanied by a systolic thrill and located at the second left interspace. Diastolic murmurs are extremely rare. The second sound in the pulmonary area is often clear and diminished in intensity, but a normal or loud P_2 may be noted. The liver is usually neither enlarged nor pulsating, but in the more severe forms or advanced stages an enlarged and pulsating liver may be noted. The systemic systolic pressure is usually at or below 100 mm. Hg and the pulse pressure is narrow.

The values for hemoglobin, red cells and hematocrit are usually normal and the circulation time is normal or slightly prolonged.

The electrocardiographic tracings reveal right axis deviation, right ventricular hypertrophy and often tall peaked P waves, especially in limb leads II and III, suggesting right atrial enlargement or strain. Changes in the T waves [illegible] myocardial strain may be noted in the more severe and advanced [illegible]

[illegible] examination reveals the heart to be normal or moderately enlarged. The apex is often elevated and the pulmonary conus convex. The [illegible] main branches at the hilus are usually large but [illegible] the left pulmonary artery may be seen at times The lung fields themselves are clear Right ventricular enlargement is suggested in the frontal view and is confirmed by rotating the patient in the oblique positions *In contrast to the tetralogy, the pulmonary window is* not clear Roentgenograms confirm the fluoroscopic findings and demonstrate decreased *vascular markings in the outer two-thirds of the lung fields*

Cardiac catheterization reveals that pressures in the right atrium are usually elevated The systolic pressure in the right ventricle is always elevated and seems to be directly related to the degree of stenosis, it may be lower, equal to, or higher than the systemic systolic pressure The occurrence of a pressure in the right ventricle which is significantly higher than the systemic systolic pressure is, for practical purposes, diagnostic of pulmonic *stenosis with an intact ventricular septum On the other hand, in all malformations* having a large ventricular septal defect, the systolic pressure in the right ventricle usually approximates the systemic systolic pressure The pressures in the pulmonary artery as recorded by conventional means may be normal, but are usually decreased If the internal diameter of the stenosis (as described in the surgical and anatomic protocols) is compared to the external diameter of the catheters used, the validity of the pressure recordings beyond the stenosis, where measured by such conventional means, may be questioned, it seems reasonable to assume that, at least in the more severe stenoses the passage of the catheter through the narrowed area would add an extra "stenosing" factor and would thus contribute to the decreased pressure recorded in the pulmonary artery If this is true, the pressures recorded *directly from the pulmonary artery (not via the right ventricle)* would be expected to be higher than those recorded by the conventional route, again in the more severe forms of stenosis That varying degrees of pulmonary hypertension *may* be found in association with pulmonary stenosis has been verified in rare instances[11, 22, 20] The importance of the recognition of such *occurrence is obvious when one contemplates surgery for the purpose of in*creasing pulmonary blood flow since the surgical procedure would then add a potentially hypertensive factor to an already existing pulmonary hypertension

The oxygen studies performed on samples of blood obtained at cardiac catheterization reveal no evidence of intracardiac shunts Measurement of the pulmonary capillary blood flow may reveal evidence of an extracardiac arteriovenous shunt if a collateral circulation has been established between the bronchial and the pulmonary arteries, and thus the total pulmonary blood flow will exceed the systemic blood flow In the absence of shunts the pulmonary and systemic blood *flows are equal and usually decreased, but may be* normal or rarely increased Soulié and associates[illegible] have demonstrated normal or increased pulmonary blood flow in association with severe pulmonary stenosis

Angiocardiography reveals that the dye follows a normal course The significant findings which however are not constant, are the retention of dye in the right ventricle, the visualization of the poststenotic pulmonary artery dilatation and the decreased vascular markings in the outer two thirds of the lung fields. These, however, are only indirect diagnostic signs of pulmonary stenosis; the stenotic area can be directly visualized roentgenographically only by special angiocardiographic technique employing the direct injection of the dye into the entrance of the outflow tract of the right ventricle. Special apparatus must be used in order to obtain the necessary films which will demonstrate both the site and the degree of stenosis.

Trilogy of Fallot.—The trilogy of Fallot may be indistinguishable from pure pulmonic stenosis if the right to left shunt at the atrial level is insignificant. With larger shunts, however, cyanosis, although it may be absent early, is usually present. It is first noted on exertion and progresses slowly. The cyanosis is usually mild to moderately intense and is predominantly central in origin, being the result of a venous-arterial shunt at the atrial level; peripheral venous unsaturation may contribute to its intensity. Associated with the cyanosis are polycythemia and, at a later date, clubbing of the fingers and toes. In the presence of a large right to left shunt there is a decrease in the circulation time. The pressures in the right atrium are almost always elevated and the shunt is from right to left. In some instances a bidirectional shunt at the atrial level may occur, but it is predominantly from right to left. If the diagnosis of pulmonic stenosis with an intact ventricular septum has been established, the passage of the catheter through an interatrial communication differentiates a pure pulmonic stenosis from a trilogy of Fallot. In the presence of a large right to left shunt, angiocardiography will initially reveal rather poor opacification of the left atrium, ventricle and aorta, followed later by reopacification of these chambers and aorta, and the systemic blood flow will exceed the pulmonary blood flow.

Differential Diagnosis of Valvular and Infundibular Stenosis.—At the present time valvular stenosis cannot be positively differentiated clinically from infundibular or combined stenosis. In the tetralogy of Fallot, where the stenosis is predominantly infundibular, the murmur is usually located lower along the left sternal border in the third to fourth interspace. On the other hand, in pulmonic stenosis with intact ventricular septum, where the stenosis is usually valvular in type, the murmur is loudest in the second left interspace. More clinical data will be necessary to determine whether the same correlation will be found between the location of the murmur and the site of the stenosis when the ventricular septum is intact.

The presence of a split second sound at the base tends to exclude the di[illegible] stenosis. Whenever this finding is present in associa[illegible] pulmonic stenosis with an intact ventricular [illegible] infundibular stenosis with a normal [illegible]

[illegible] the pul[illegible] segment suggests the [illegible] pulmonary artery and thus [illegible] Fig. 1 [illegible] smallness or-

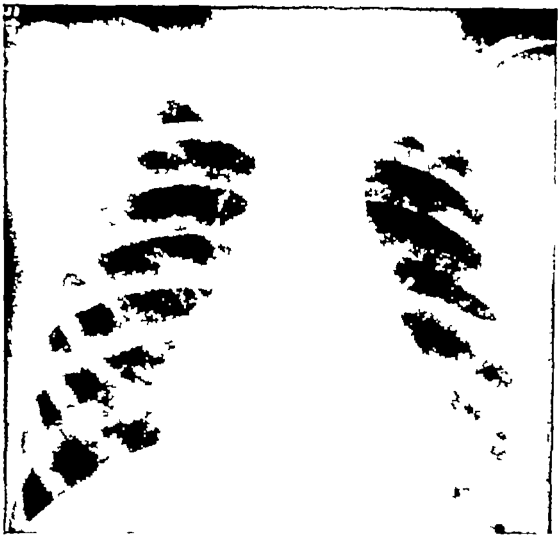
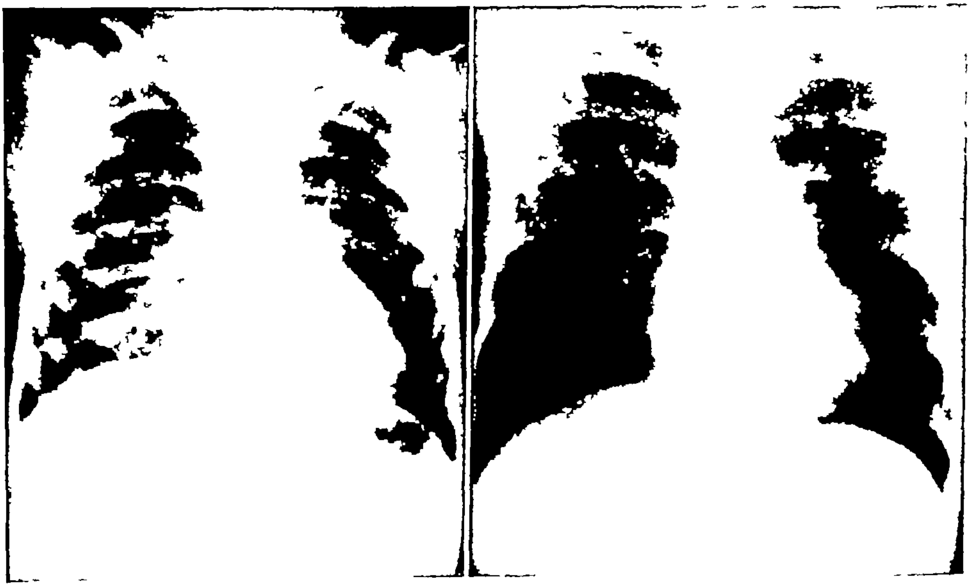


Fig. 1.—Typical posteroanterior roentgenogram of pure valvular pulmonic stenosis. Note the fullness and convexity of the pulmonary artery segment on the upper left border of the cardiac silhouette produced by poststenotic dilatation.



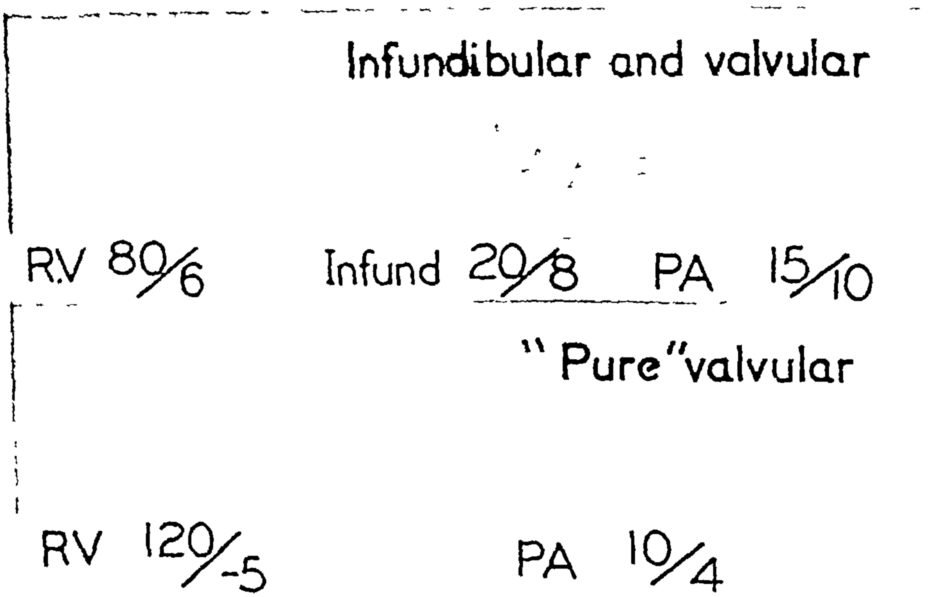
A

B

Fig. 2.—Posteroanterior roentgenograms of pure infundibular pulmonic stenosis. Although there is usually a concavity in the region of the pulmonary artery segment as in A (Case 4) there may be a convexity as in B (Case 1) which may confuse the diagnosis on purely radiographic grounds.

concavity of the pulmonary artery segment, on the contrary, suggests the presence of a normal or hypoplastic pulmonary artery with an infundibular rather than a valvular stenosis (Fig. 2 A). The presence of a right aortic arch tends to produce a straight or full shadow in the region of the pulmonary artery segment, and its occurrence must be considered when evaluating this segment.

The continuous recording of pressures while withdrawing the catheter from the pulmonary artery under fluoroscopic guidance is the best available method of differentiating the various types of stenosis. In *pulmonary valvular stenosis* there is a sharp rise of the systolic pressure and a fall of the diastolic pressure to zero or negative values at the level of the pulmonary valve (Fig. 3). In *infundibular stenosis* the systolic pressure is approximately the same



[illegible]

in the pulmonary artery [illegible] and in the infundibulum distal to the stenosis, proximal to the stenosis, however, there is a sharp rise in the systolic pressure [illegible] at the level of the pulmonary valve and [illegible] remains [illegible] proximal and distal to the stenosis. In *combined* [illegible] there is [illegible] in the systolic pressure in the [illegible] and the infundibular stenosis, followed by [illegible] valvular stenosis [illegible] the diastolic pressure [illegible]

At the time of surgery the site and degree of stenosis can be ascertained by both extra- and intracardiac exploration In valvular stenosis varying degrees of poststenotic dilatation are usually noted in the pulmonary artery and a systolic thrill is palpable distal to the valve, by digital invagination of the pulmonary artery the orifice of the pulmonary valve can be obliterated with resultant disappearance of the thrill The pulmonary valve can be palpated as a stiff, dome-shaped structure, a high and short infundibular stenosis located immediately subjacent to the valve may simulate these findings In the typical infundibular stenosis, however, the thrill is best felt in the wall of the outflow tract of the right ventricle distal to the site of the stenosis, although it may extend into the pulmonary artery *A short infundibular stenosis of the* diaphragmatic type (membranous infundibular stenosis) produces a poststenotic thin-walled ventricular chamber The more common, long, narrow infundibular stenosis (myocardial infundibular stenosis) is usually associated with hypertrophy of the outflow tract Combined infundibular and valvular stenoses are frequently associated with a hypoplastic pulmonary artery

The value of pressure recordings at surgery for the localization of the primary obstruction and for the demonstration of other obstructions has been pointed out by Kirklin and associates [23]

The functional significance of pulmonic stenosis, especially of the infundibular type, is better appreciated by cardiac catheterization, selective angiocardiography, and surgical exploration than by direct visualization at necropsy The striking difference in the appearance of the pulmonary arteries at the time of surgery and at post-mortem examination in patients with tetralogy of Fallot has been stressed by Soulié, in like manner the stenosis as well as the poststenotic dilatation in patients with pulmonic stenosis with an intact ventricular septum may be more striking in vivo than at the autopsy table

Indications for Surgery—No definite criteria for the surgical treatment of pulmonic stenosis with an intact ventricular septum have been established Severe hypertension in the right ventricle with an elevated diastolic pressure or a great reduction in the pulmonary blood flow are definite indications for surgical intervention The level of right ventricular hypertension which should serve as an indication for surgical correction varies with different authors from 50 to 100 mm Hg systolic Systolic pressures above 100 mm Hg are generally accepted as indicating the need for surgical intervention Polycythemia, stunting of growth, electrocardiographic evidence of severe right ventricular hypertrophy and myocardial strain indicate the need for surgical treatment From the experience of several writers it appears that the age of the patient must be considered in evaluating the indications for surgery, the higher mortality figures occurring among those patients under 2 years and beyond 20 years of age In general this same variation in surgical mortality rates as related to age applies to all forms of congenital heart diseases

Surgical Technique—Although the direct and the indirect approaches have been successfully used to increase pulmonary blood flow in patients with the tetralogy of Fallot, only the direct approach should be used in patients with pulmonic stenosis with an intact ventricular septum In the few in-stenosis in which systemic pulmonary artery anastomosis has been used[3, 11] For this condition the operation was invariably followed by right sided failure. Relief of the strain on the right side of the heart is the primary goal and an increase of pulmonary blood flow follows. According to the type of stenosis therefore valvotomy and or infundibular resection must be used.

The technique as used by the authors has been presented in detail in previous communications.[3, 7, 11] Certain modifications based on a greater experience should be stressed. A rectangular flap of pericardium is raised medially after access to the heart has been obtained through a left parabolic submammary incision entering the pleural space through the third anterior interspace. The entire outflow tract of the right ventricle and the roots of the great vessels are thus exposed. Adequate time must be taken for careful inspection and palpation of these structures as numerous variations in anatomic detail may at first be confusing. As a rule the infundibular chamber will consist of a muscular wall similar to but a little thinner than the right ventricular myocardium proximal to it. Frequently the wall will be membranous and similar in consistency and texture to the structure of the pulmonary artery. In this instance it may be difficult to differentiate immediately between the chamber and the artery but further inspection and exploratory intracardiac probing should clarify the situation. That infundibular stenosis is present is detected by a systolic thrill proximal to the pulmonary valve at the root of the pulmonary artery. The absence of poststenotic dilatation of the pulmonary artery and the inability to delineate a fused pulmonary valve cone with its jetlike systolic flow when digitally invaginating the flaccid arterial wall lend further evidence that the stenosis is infundibular rather than valvular.

Of greatest importance is the accurate localization of the level of maximal infundibular obstruction for it is directly over this point that the transventricular incision should be made when employing this technique. This area can be recognized in a number of ways. It is the point where the systolic thrill is rather abruptly lost when passing the finger along the wall of the chamber away from the pulmonary artery. In addition numerous twiglike coronary branches can often be seen to encircle the lower border of the infundibular chamber [illegible] out from the more perpendicularly placed larger coronary vessels running over the interventricular septum. Most accurate localization [illegible] obtained by intraventricular exploration first with a small malleable [illegible] next with [illegible] urethral sound and finally with the long shafted [illegible]

[illegible]

[illegible] instruments in turn is gently passed through the myocardium [illegible] an incision and the infundibular resecting [illegible] Each is passed upward through the in[illegible] artery where it can be readily palpated [illegible] to determine the [illegible] the valve [illegible] and gradually [illegible] the infundibular [illegible]

[illegible]

may vary from a peanut to a lemon in size As the infundibular ridge or crest is approached, the instrument will ride up over it only to fall off downward into the large lumen of the right ventricle proper By rocking the instrument gently back and forth over the hypertrophied muscular or membranous crest very accurate localization can be obtained The jaws of the resector can then be opened, the full thickness of the crest engaged, and a generous bite removed within the mouth of the instrument (Fig 4) This may

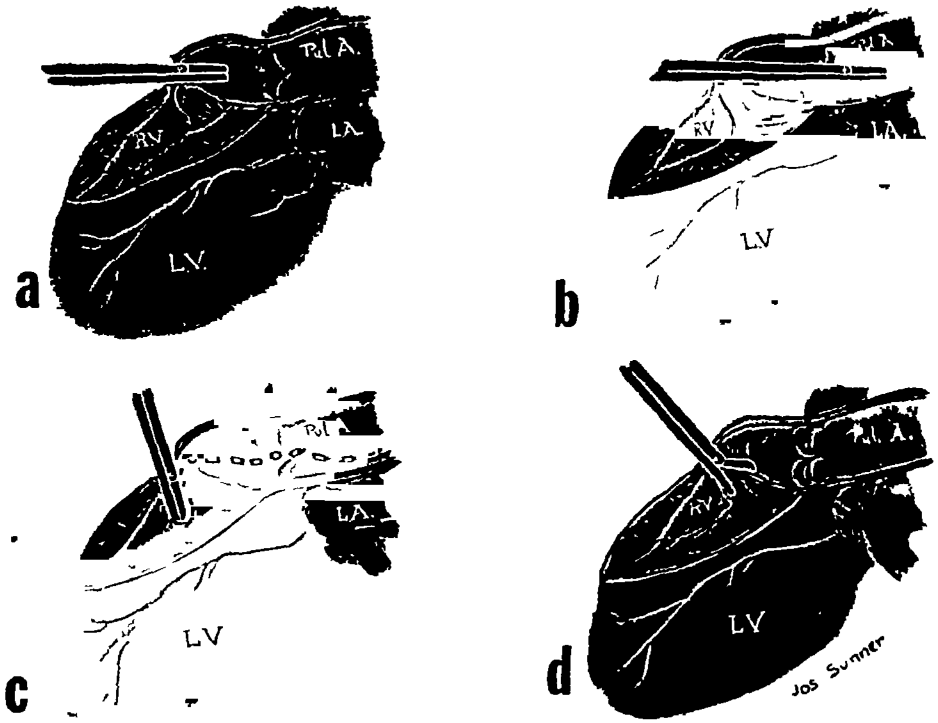


Fig 4 —The authors m [illegible] resection *a* The resecting instrument is inserted through the myocardi [illegible] infundibular obstruction *b* The instrument is passed into the pulmonary [illegible] us of the valve can be palpably determined The jaws of the instrument can be opened at this level to further evaluate the valve area *c* The instrument is slowly withdrawn in contact with the floor of the outflow tract. It rides over the obstruction and falls into the right ventricle providing accurate localization *d* The jaws are opened and a portion of the obstructing ridge resected This can be repeated until most of the ridge has been removed

be repeated three or four times until an entirely adequate channel has been fashioned after which the infundibular chamber will swell and become tense The same increased pulmonary flow and pressure will be noted within the pulmonary artery and the thrill, previously soft and localized, will usually become coarse and generalized If facilities are available, it is advantageous to measure directly the pressures within the ventricle, chamber, and artery, for in this way the completeness of the resection can more readily be determined A most adequate result can be obtained however without these refinements because sight and the sense of touch are usually sufficient

With reasonable care one need have little fear during such a resection for the ventricular septum is intact and no vital structures can be encountered and accidentally injured. When employing this technique in the tetralogy of Fallot in which there is a large interventricular septal defect lying just beneath the infundibular ridge the resector must be directed away from the aorta toward the septum to avoid the anterior cusp of the aortic valve which may recoil into the opening of the septal defect. It is wise under these circumstances to time the resecting bite in ventricular systole at a time when the valve leaflets are flattened against the aortic wall. Bleeding from the myocardium is easily controlled between bites by digital pressure or by crossing the initially placed stay sutures. Two or three interrupted sutures of fine cotton are sufficient to close the small myocardial wound.

Postoperative Changes.—Following a successful valvotomy or infundibular resection the portion distal to the stenosis will be full, tense and a conspicuous resistance to compression is palpable. The tolerance to activity increases and cyanosis, if present, usually disappears at or shortly after surgery. The murmur and thrill may change in intensity, become more diffuse or occasionally disappear; some murmur, however, persists. Some degree of increased cardiac enlargement (radiographic silhouette) often occurs shortly after operation and persists for variable periods of time. This may be evidence of a successful operation since cardiac enlargement may be the result of decompensation secondary to increased cardiac output. The pulmonary vessels usually appear more conspicuous and pulsate more vigorously than before the operation. The electrocardiographic tracings frequently reveal inversion of the T waves, these returning to normal after a period of a few months. A longer follow up is necessary to determine the rapidity of the regression of the electrocardiographic evidence of right ventricular hypertrophy. More postoperative physiologic studies are necessary before the course of the hemodynamic changes can be predicted. While some have demonstrated a significant decrease of pressure in the right atrium and ventricle,[illegible] others have found no significant changes. Some increase of the pulmonary blood flow [illegible] and the peripheral arterial oxygen saturation, if previously low, rises [illegible] normal levels. From the work of the group at the Mayo Clinic it seems probable that the hemodynamic changes are directly related to the degree of [illegible] that can be achieved by surgery. To achieve normal [illegible] in pulmonic stenosis with an intact ventricular septum as much of the [illegible] should be removed as possible. This probably is not true when [illegible] technique (the direct approach) is used for pulmonic stenosis [illegible] ventricular septal defect. Here less extensive surgery [illegible] desirable [illegible] it results in adequate pulmonary blood flow [illegible] hypertension. Furthermore, irrespective of [illegible] resection or valvular incision the pressure in the right [illegible] will remain practically unchanged. Although [illegible] placed on the prognostic importance of post[illegible] regular clinical follow up cannot and [illegible] of operation [illegible] results [illegible]

Mortality—The patient with pulmonic stenosis with an intact ventricular septum usually progresses from an asymptomatic period to a period of increased symptoms, followed by rapid deterioration terminating in right-sided cardiac failure Prior to surgery the life expectancy averaged 25 to 30 years[34]

In our experience the mortality from direct intracardiac valvotomy and infundibular resection varies considerably with the type of malformation for which they are used Whereas in tetralogy of Fallot and in tetralogy-like malformations the over-all mortality has been 20 per cent in a total of 60 cases operated upon (less than 10 per cent in the last 25 cases), in pulmonic stenosis with an intact ventricular septum there have been no deaths in a total of 25 cases treated (19 valvular, 4 infundibular, and 2 both valvular and infundibular)

CASE REPORTS

CASE 1—B T, a 9 year old white girl, was admitted to St Christopher's Hospital for Children because of exertional dyspnea, easy fatigability, and "squatting" since the age of 4 years A cardiac murmur had been first noted at the age of 10 days

Physical examination revealed a thin but well developed girl with slightly dusky appearing nail beds Blood pressure was 102/72 There was a harsh Grade 4 systolic murmur and a thrill present in the second and third left interspaces P_2 was diminished (Table I)

The hemoglobin at the time of admission was 14 3 Gm, erythrocytes 4 62 millions per cubic millimeter The hematocrit was 51 Her circulation time (arm to tongue) was 9 sec

TABLE I CLINICAL MANIFESTATIONS AND ELECTROCARDIOGRAPHIC FINDINGS IN PULMONIC STENOSIS (INFUNDIBULAR)

	AGE (YR)	DYSPNEA	CYANOSIS	SQUATTING	MURMUR	THRILL	P_2	POLYCYTHEMIA	ELECTROCARDIOGRAM
Case 1 B T Female	9	On exertion		Yes	Systolic, II III	Systolic, II III	Diminished		RAD RVH
Case 2 M L Male	5	On exertion			Systolic, III	Systolic, L S B	Diminished		Peaked P_2 RAD RVH
Case 3 J B Female	13	On exertion		Yes	Systolic, left base	Systolic, left base	Not split diminished	Mild	Peaked P_2 RAD RVH
Case 4 T M Male	6				Systolic, III	Systolic, II IV	Diminished		Extrasystoles RAD RVH
Case 5 R B Female	6	On exertion	Moderate		Systolic, II III	Systolic, L S B	Diminished	Mild to moderate	Peaked P_2 RAD RVH
Case 6 G H Female	3	On exertion		Yes	Systolic II III	Systolic, II III	Diminished, clear	Mild to moderate	RAD RVH

II III = Second and third interspaces
RAD = Right axis deviation
RVH = Right ventricular hypertrophy
L S B = Left sternal border

The electrocardiographic tracing revealed right axis deviation and right ventricular hypertrophy. Roentgenograms and fluoroscopic examination of the chest revealed the heart to be of normal size and contour; the pulmonary artery segment was slightly convex.

The preoperative results of cardiac catheterization and of angiocardiography are listed in Tables II and III.

TABLE II. RESULTS OF CARDIAC CATHETERIZATION IN PATIENTS WITH PULMONIC STENOSIS (INFUNDIBULAR)

(Preoperative)

	OXYGEN (VOL. PER CENT)						PRESSURES (MM. HG)			
	S.V.C.	I.V.C.	R.A.	R.V.	P.A.	F.A.	R.V.	INF.	P.A.	B.A.
Case 1 R.B.T. Female Age 1[illegible]	12.0	—	12.0	13.8	—	87%	40/0	—	—	102/72
Case 2 M.I. Male Age [illegible]	12.[illegible]	12.[illegible]	12.[illegible]	11.7	12.6	92.8%	75/0	40/0	26/15	100/80
Case 3 I.B. Female Age [illegible]	11.[illegible]	—	11.7	10.[illegible]	—	87.9%	134/0	—	—	100/74
Case 4 T.M. Male Aged [illegible]	8.1	—	8.2	8.1	8.2	93%	150/0	28/0	20/12	90/60
Case 5 [illegible] P. Female Age 1[illegible]	12.9	—	11.3	11.6	1[illegible]	84%	120/-5	—	10/4	100/70
Case 6 G.H. Female Age 13	11.1	12.02	11.0	11.[illegible]	—	87%	100/-5	55/0 80/0	—	86/60

S.V.C. Superior vena cava
I.V.C. Inferior vena cava
R.A. Right atrium
R.V. Right ventricle
P.A. Pulmonary artery
F.A. Femoral artery
INF. Infundibular chamber
B.A. Brachial artery

[illegible] 1951. The preoperative diagnosis was pulmonic [illegible] At operation the thrill was maximum in the thin [illegible] infundibular chamber (Fig. 5). Intracardiac digital ex[illegible] infundibular chamber revealed a normal pulmonary valve and [illegible] infundibular chamber [illegible] Digital dilatation with a dilator [illegible] Resection of the [illegible] portion of [illegible] successful.

[illegible] within two [illegible] Her [illegible] The cardiac [illegible] small

[illegible]

TABLE III. ROENTGENOGRAPHIC OBSERVATION IN PULMONIC STENOSIS (INFUNDIBULAR)

	CARDIAC ENLARGEMENT	PULMONARY ARTERY SEGMENT	HILAR VESSELS	PERIPHERAL LUNG FIELDS	ANGIOCARDIOGRAM
Case 1, B. T., Female	None	Convex	Prominent pulmonary artery, quiet	Not Remarkable	Enlarged right ventricle and pulmonary artery, no shunts
Case 2, M. L., Male	None	Concave	Quiet	Clear	
Case 3, J. B., Female	Right atrium and ventricle	Concave		Clear	Prolonged retention of dye in right ventricle, no right to left shunt
Case 4, T. M., Male	None	Normal	Average, quiet	Not Remarkable	
Case 5, R. B., Female	None	Concave	Average, quiet	Clear	Selective, no injection of aorta, compatible with diagnosis of pulmonic stenosis with intact ventricular septum
Case 6, G. H., Female	Right atrium and ventricle	Concave	Right arch, average, quiet	Clear	Poor opacification of left cavities and aorta in dextroangiogram, late reopacification in levo angiogram delay dye in right ventricle, right arortic arch

interspace. A systolic thrill was palpable along the left sternal border. P was diminished (Table I.) There was no demonstrable cardiac enlargement.

The hemoglobin at the time of admission was 14.3 Gm., erythrocytes were 5.18 million per cubic millimeter, hematocrit 44. The circulation time was 9.8 seconds. Electrocardiographic tracings revealed peaked P waves in limb Lead II and evidence of right axis deviation and right ventricular hypertrophy.

Roentgenograms and fluoroscopic examination of the chest revealed the heart to be of normal size. The apex was upturned, the pulmonary conus was concave, and the hilar vessels were quiet. Vascular markings at the periphery of the lungs were reduced. The right ventricle was prominent as viewed in the left anterior oblique.

The results of cardiac catheterization (done elsewhere) are listed in Table II and these suggested an infundibular stenosis with an intact ventricular septum.

Surgery was performed on Oct. 27, 1952. The pulmonary artery was the size of one's thumb, but there was no poststenotic dilatation. *A thrill was palpable over the outflow tract* of the right ventricle extending up into the pulmonary artery. Intracardiac exploration failed to reveal any valvular stenosis. There was an infundibular obstruction with an "infundibular chamber the size of a walnut" (Fig. 6). No other defects were noted. After infundibular resection (three bites) the pulmonary artery was more tense and the thrill over this area was harsher and more generalized.

The patient's immediate postoperative condition was good. Mild cardiac enlargement was noted roentgenographically. Seven months later he had steadily improved and his physical activity had increased considerably. Dyspnea following exertion was no longer a complaint. There were no *significant changes* noted over those found preoperatively in the physical examination, in roentgenograms, in fluoroscopic examination of the chest, or in the electrocardiographic tracings.

At present he is asymptomatic, although there is "some dyspnea on severe exertion." Repeat cardiac catheterization carried out fourteen months after surgery revealed *the* right ventricular pressures to have dropped from 75/0 to 40/0, infundibular chamber pressures from 40/0 to 30/0. The pressures in the main pulmonary artery were essentially unchanged, 26/15 before and 25/8 fourteen *months later.**

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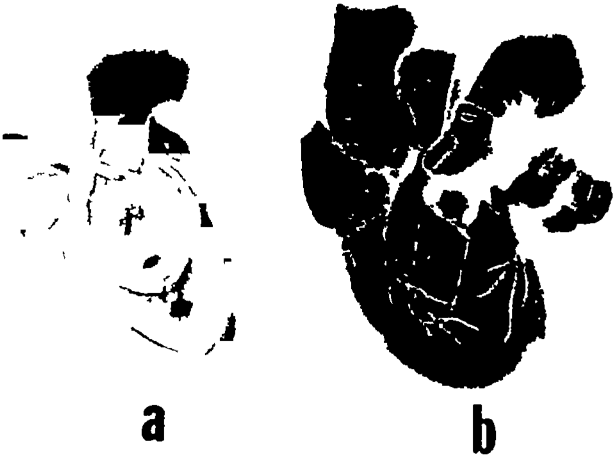
*These catheterization data (pre- and postoperative) were obtained through the courtesy of Dr. Paul La Bissoniere, Marquette University School of Medicine, Milwaukee, Wis.



[illegible] actually [illegible] infundibular chamber (Case 1). In this instance the [illegible] were actually divided into two halves approximately equal in size. The [illegible] by the index finger which was thrust through the opening [illegible]. No resection could be performed in this instance.

[illegible]

CASE 3—J B, a 13 year old white girl, had never been cyanotic, but a cardiac murmur had been noted since birth At 10½ years of age she began "squatting" to relieve precordial pain and at 12 years exertional dyspnea and easy fatigue were noted

Physical examination at the time of admission to Presbyterian Hospital revealed a well developed, well nourished girl with a blood pressure of 100/74 There was a harsh systolic murmur, loudest at the left base, and a systolic thrill was palpable along the left sternal border The second sound in the pulmonic area was not split (Table I) Cardiac enlargement was noted on physical examination, as were congenital deformities of the hands and arms

Her hemoglobin was 16 Gm, erythrocytes were 5 27 millions per cubic millimeter The electrocardiographic tracings revealed peaked P waves, right axis deviation, and evidence of right ventricular hypertrophy Roentgenograms and fluoroscopic examination of the chest revealed cardiac enlargement, confined to the right atrium and ventricle The pulmonary conus was concave and the vascular markings were reduced

The results of cardiac catheterization and angiocardiography, done elsewhere, are listed in Tables II and III

Surgery was performed on Jan 22, 1953 The pulmonary artery was the size of one's index finger and very flabby A rather faint thrill was palpable over the pulmonary artery, and proximal to the pulmonary valve there was an "egg sized," thin walled infundibular chamber where the thrill was maximal (Fig 6) Intracardiac exploration revealed a normal pulmonary valve and a severe infundibular obstruction, the ventricular septum was intact Extensive infundibular resection (four bites) was performed The heart rate slowed, but picked up immediately after intracardiac manipulation ceased

The immediate postoperative condition was good and two months later dyspnea had greatly reduced, the appetite had improved The significant changes on physical examination were the absence of the thrill and the presence of a Grade 1 diastolic murmur over the pulmonic area Roentgenograms revealed an obvious decrease in the heart size Her hemoglobin was 13 Gm and the erythrocytes 4 47 million per cubic millimeter The electrocardiographic tracings revealed a migrating atrial pacemaker and a right bundle branch block in addition to the preoperative findings These findings have now disappeared

At present this patient is completely asymptomatic and lives a normally active life, including dancing at school parties Recent cardiac catheterization carried out thirteen months after surgery revealed the right ventricular pressures to have dropped from 134/0 to 80/–1 in the mid right ventricle and 80/0 high in the right ventricle The pressure in the right pulmonary artery was 15/7 *

CASE 4—T M, a 6 year old white boy, was admitted to St Christopher's Hospital for Children for cardiac evaluation A cardiac murmur was first noted at the age of 3 years He had never been cyanotic He had no cardiac symptoms

Physical examination revealed a well developed, well nourished boy with a blood pressure of 92/60 A systolic thrill was palpable along the left sternal border from the second to the fourth interspace and a harsh Grade 4 systolic murmur was maximal at the third left interspace (Table I) P_2 was diminished and frequent premature contractions were heard

The hemoglobin at the time of admission was 10 5 Gm erythrocytes were 3 78 millions, the hematocrit 35 The electrocardiographic tracings revealed right axis deviation, right ventricular hypertrophy, and frequent premature contractions Roentgenograms and fluoroscopic examination of the chest revealed the heart to be of normal size and contour, the hilar vessels were of normal caliber and quiet

The results of cardiac catheterization are listed in Table II

Surgery was performed on Sept 28, 1953 At operation the pulmonary artery was of normal size, an infundibular obstruction could be demonstrated 3 cm proximal to the pulmonary valve (Fig 6) On palpation a rough systolic thrill was maximal over the outflow tract of the right ventricle propagated faintly to the pulmonary artery Intracardiac ex

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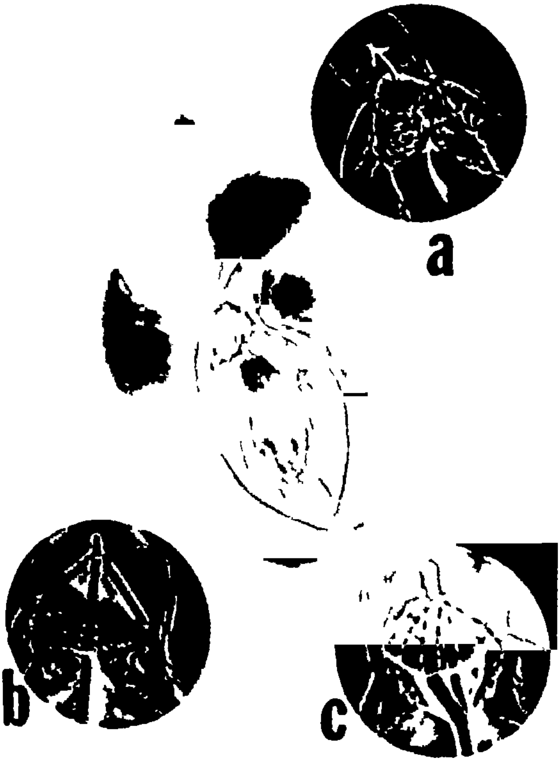
*These catheterization data (pre and postoperative) were obtained through the courtesy of Dr Chester Kurtz at the Wisconsin General Hospital Madison Wis palpation revealed a diaphragm-like obstruction with a poststenotic infundibular chamber. The pulmonary valve appeared normal; no ventricular septal defect was noted. Following infundibular resection (four but [illegible]) the tension in the pulmonary artery increased.

The immediate postoperative condition was good although the patient developed mild cardiac enlargement and early signs of decompensation, which immediately responded to digitalization. Four months later he was in full activity without medication and had no complaints. At four and at six months following surgery there were no changes on physical examination. Roentgenograms and fluoroscopic examination of the chest revealed mild cardiac enlargement, especially of the right atrium on frontal view; there was mild prominence of both ventricles in the oblique views. The hilar vessels were adequate and pulsating. The electrocardiographic tracings revealed no changes.

At present he remains asymptomatic and normally active as he was prior to surgery.

CASE 7.—K. B., a 6-year-old white girl, was admitted to St. Christopher's Hospital for Children because of cyanosis and dyspnea on exertion since the age of 4 years. She was not cyanotic at birth. A cardiac murmur and enlargement were first noted at 6 months. A few [illegible] prior to admission clubbing of the fingers and toes was noted.



[illegible]

Hemoglobin was 16 7 Gm, erythrocytes were 6 2 millions per cubic millimeter, the hematocrit was 53 The electrocardiographic tracings revealed peaked P waves in limb Lead II, right axis deviation, and evidence of right ventricular hypertrophy Roentgenograms and fluoroscopic examinations of the chest revealed the heart to be of normal size, the conus was concave and the vascular markings reduced In the oblique views there was marked prominence of the right ventricle

The results of cardiac catheterization and selective angiocardiography are listed on Tables II and III

Surgery was performed on Oct 26, 1953 The pulmonary artery was the size of one s little finger and there was no poststenotic dilatation The right and left branches were larger than the main pulmonary artery The pulmonary artery was severely constricted as it emerged from the right ventricle, and a systolic thrill was palpable along the trunk The usual cone like pulmonary valve was not palpable Intracardiac exploration revealed the obstruction to be immediately subvalvular, the ventricular septum was intact (Fig 7) Valvotomy was performed through the infundibular and valvular obstructions followed by extensive dilatation to a size of 2 cm. by actual intraluminal measurement The constricted region was now filled out, the pulmonary artery seemed tense and full and the thrill became more diffuse

Postoperatively she developed early signs of decompensation and was digitalized Two months later physical examination revealed decrease in the cyanosis and the disappearance of the thrill, otherwise the findings were the same as preoperatively Fluoroscopic examination of the chest revealed adequate hilar vessels with normal pulsations Digitalis therapy was discontinued and activity increased

At present she is practically asymptomatic and acyanotic Further time must elapse before her ultimate status can be ascertained

CASE 6 —G H, a 3 year old Negro girl, was admitted to St Christopher s Hospital for Children because of exertional dyspnea, easy fatigability, squatting, and questionable cyanosis on exertion A cardiac murmur was first noted at the age of 2 years

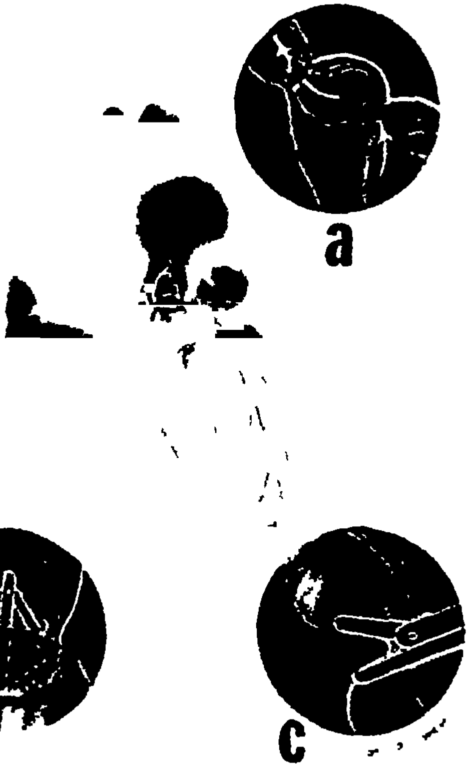
Physical examination on admission revealed a small, thin girl with a blood pressure of 86/60 A Grade 3 harsh systolic murmur was maximal at the second and third left interspaces a systolic thrill was palpable in the same location P_2 was clear (Table I)

Hemoglobin was 17 2 Gm, erythrocytes 5 1 millions per cubic millimeter, the hematocrit 55 The electrocardiographic tracings revealed right axis deviation and evidence of rather severe right ventricular hypertrophy Roentgenograms and fluoroscopic examination of the chest revealed a mild cardiac enlargement with prominence of the right atrium and ventricle The conus was slightly concave and the vascular markings were reduced A right aortic arch was noted

The results of cardiac catheterization and angiocardiograms are listed in Tables II and III

Surgery was performed on Nov 23, 1953 At operation the pulmonary artery was 12 mm in diameter, very short, and had an area of constriction in its mid portion A rather faint thrill was palpable in the pulmonary artery, maximal immediately distal to the pulmonary valve Intracardiac exploration revealed an infundibular obstruction with a poststenotic infundibular chamber the "size of a peanut" (Fig 8) The pulmonary valve appeared constricted and the ventricular septum was intact Valvotomy, infundibular resection and dilatation of the constricted segment of the pulmonary artery were performed The infundibular chamber and the pulmonary artery became more full and tense, the thrill increased in intensity and became more widespread

Postoperatively she developed right sided failure (palpable liver) and was placed on digitalis with good response Two months later digitalis was discontinued and physical activity increased Four months following surgery she was in full activity and had no complaint Squatting was no longer noted Physical examination revealed essentially the same findings as preoperatively except for increased intensity in the murmur and thrill Roentgenograms and fluoroscopic examination of the chest revealed a mild cardiac enlargement and increased vascular markings



[illegible] infundibular and valvular stenosis with an intervening [illegible] (a) [illegible] and (c) the valvular incision and the infundibular resection.

COMMENTS

Half of the patients gave a history of squatting. Easy fatigability and dyspnea on exertion were the major complaints in all but one patient. There was no apparent relation between the height of the pressures in the right ventricle and the severity of the symptoms. This lack of correlation has been observed by others. Pain in the precordium, cyanosis, and early clubbing [illegible] occasion. There was moderate polycythemia in [illegible] polycythemia in one.

[illegible] were mildly impaired in two patients. In [illegible] murmur was loudest either in the second or third left [illegible] palpable along the upper left sternal border. [illegible] was present and diminished in every [illegible]

[illegible] observed by [illegible]

uniformly quiet The lung fields showed decreased vascular markings in four instances, in two they appeared normal A right aortic arch was present in one patient

Right axis deviation and evidence of right ventricular hypertrophy were seen in all electrocardiographic tracings Peaked P waves equal to or greater than 2 5 mm were present in one-half of the tracings Frequent premature contractions were seen in one patient, these persisted postoperatively

In three cases conventional angiocardiography revealed prolonged retention of dye in the right ventricle Early, rather poor opacification of the aorta was seen in one additional patient, the result of a shunt from the right to the left atrium, this was the only such shunt demonstrable by the dye studies

The pressures in the right ventricle were moderately to markedly elevated in five of the patients The pulmonary artery was entered in three patients and in these the pressure was either normal or decreased A gradual rise in the systolic pressure in the right ventricle was noted in three patients as the catheter was withdrawn The systemic systolic pressure was near or under 100 mm Hg in all patients and the pulse pressure was never greater than 30 mm Hg In three patients the systolic pressure in the right ventricle exceeded the systemic systolic pressures No evidence of any left to-right shunt was obtained by cardiac catheterization, a right-to left shunt at the atrial level was suggestive in four patients (femoral artery oxygenation below 90 to 94 per cent) but questionable in two (Cases 2 and 4, Table II)

The diagnosis of pulmonic stenosis in this series was made on the basis of right ventricular hypertension and a diminished pressure in the pulmonary artery in those patients in whom the pulmonary artery was entered In the remaining three patients the diagnosis was suggested by a combination of the clinical and laboratory findings, including right ventricular hypertension and roentgenographic evidence of a decreased pulmonary blood flow

The presence of an intact ventricular septum was assumed from the oxygen studies which revealed an absence of any left-to right shunting at the ventricular level The finding of a systolic pressure in the right ventricle significantly higher than the systemic systolic pressure gave additional support to the presence of an intact ventricular septum in three cases

The infundibular location of the stenosis was suggested by (1) the finding of a pressure gradient as the catheter was withdrawn from the pulmonary artery and/or infundibulum, (2) difficulty in catheterizing the pulmonary artery, (3) concavity of the conus or absence of poststenotic dilatation, and (4) localized angiographic evidence of a small pulmonary artery with infundibular irregularities

The diagnosis of an interatrial communication was proved or suggested (1) by the direct passage of the catheter from right to left atrium or (2) by the determination of the arterial oxygen saturation which revealed a peripheral arterial unsaturation in the presence of an intact ventricular septum

At operation the ventricular septum was found intact by probing in all instances. In Cases 1 to 4 there was in addition considerable narrowing of the trunk of the pulmonary artery. Case 5 differed from the others in that the stenosis was high in the infundibulum (subvalvular) and thus presented a difficult surgical problem. In Case 6 the presence of a high systolic pressure in the infundibular chamber suggested that the significant obstruction was valvular or arterial in addition to a less significant infundibular stenosis.

RESULTS

The patients (Cases 1, 2, and [illegible]) who have been followed for the longest periods of time ([illegible] to [illegible] years) have shown definite improvement as indicated by an increase in exercise tolerance and a disappearance of symptoms. In one patient no functional change could be noted after seven months as this patient had no initial cardiac disability. The murmur changed in intensity but remained present in all patients and the systolic thrill disappeared in two patients. Mild cardiac enlargement developed postoperatively in four patients. In one in whom cardiac enlargement was present prior to surgery the size of the heart has subsequently become normal (Case 3); this was the only patient who postoperatively developed a diastolic murmur possibly indicating pulmonary insufficiency. Following surgery she developed a transient auricular [illegible] pacemaker rhythm and a right bundle branch block. Cyanosis of undiminished intensity persisted in one case (Case 5) and polycythemia disappeared in another (Case 3). The effects of surgery on polycythemia had not been determined in two patients (Cases 5 and 6). Three patients (Cases 4, 5, [illegible]) developed evidence of beginning right-sided cardiac failure which responded well to digitalis and rest; these measures were discontinued within a [illegible] weeks. Subacute bacterial endocarditis occurred in one patient seven [illegible] after surgery and was controlled by antibiotic therapy.

[illegible] four patients are now functionally normal and [illegible] recent cases show definite improvement [illegible] of seven and [illegible]

SUMMARY

1. The [illegible] with pulmonic stenosis has been reviewed and [illegible] presented.

2. [illegible] pure pulmonic stenosis are discussed with [illegible] differential diagnosis between this entity and the [illegible]

[illegible] the site of the pulmonic [illegible]

3. [illegible] pulmonary artery exploration [illegible]

sis was present, in four, pure infundibular stenosis was the obstructing lesion, and in two both forms of stenosis were encountered There was no mortality in the entire series

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[illegible] Stein, Cleveland, Mueller and [illegible] Pulmonic
[illegible]

PULMONIC VALVULAR STENOSIS

Results and Technique of Open Valvuloplasty

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PULMONARY valvular stenosis with intact interventricular septum has been recognized with increasing frequency in recent years. Usually the patient is cyanotic, although occasionally a patent foramen ovale (or rarely a true atrial septal defect) may allow a right-to left shunt of blood and thus peripheral arterial oxygen desaturation. All degrees of severity of the malformation apparently occur.[1] Many of the patients are asymptomatic for long periods of their lives, others die in infancy. In the more pronounced malformations, however, the great work-load imposed upon the right ventricle results first in its progressive hypertrophy, later in cardiac failure and death. The long-term importance of the lesion to the patient and the threat to his health is not necessarily reflected in the symptomatology, since decompensation may occur rapidly. The anomaly, therefore, when identified, cannot be considered benign. Complete physiologic evaluation is advisable and operative intervention considered in every case on the basis of such evaluation. We have recommended operation in all patients in whom the right ventricular systolic pressure exceeded 75 mm. Hg, and who showed a characteristic abrupt pressure gradient across the pulmonary valve irrespective of the presence of symptoms.

Since the reports of Sellors[2] and Brock,[3] the transventricular blind instrumental manipulation of the congenitally deformed valve has become the commonly practiced method of surgical intervention. That this is an operation which can be done at low risk has been amply demonstrated.[4-6] The purpose of the operation is to relieve the stenosis of the pulmonary valve. How efficiently it does so has been a question on which evidence has ben slow in accumulating. Only within the past year have objective data been presented evaluating this procedure. In the light of these studies it is now apparent that the transventricular instrumentation of the pulmonary valve in so called "pure" valvular stenosis, as commonly performed in many cardiac centers in this country, produces quite variable results and fails in a high percentage of cases to relieve the valvular stenosis.

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It must be emphasized again that clinical evaluation of the effectiveness of this procedure is unreliable just as it is unreliable in establishing the indications for the operation. The statement of the parents that the child is "better" or "more active" is notoriously colored by wishful thinking. Indeed in many patients there were few if any symptoms present before operation; postoperatively they are at best no worse. To determine this point requires evidence on the absolute and relative pressures existing in the right ventricle and pulmonary artery before and after valvulotomy. This evidence must be obtained before and some time after operation, *not at the time of surgery*, since data secured at the operating table after manipulation of the heart, ventriculotomy and loss of blood may be misleading. This is well known to all who have taken pressure readings during the operation following extensive cardiac manipulation and compared these with subsequent observations by cardiac catheterization following convalescence. Nothing short of preoperative and postoperative cardiac catheterizations, therefore, will yield reliable evidence on which to judge the degree of operative relief of pulmonary valvular stenosis.

About a year and a half ago our own data obtained in this fashion began to give us cause for concern. At this time we were performing the transventricular technique using the instrument devised by Potts. In the light of this data we were radical in our attitude in the manipulation of the valve, making cuts with the knife in at least two places and attempting to further dilate the valve with vigor. In spite of this attitude the results were neither uniform nor in our opinion adequate. For this reason, as soon as the method of operating during hypothermia with the cessation of circulation had reached the stage in our laboratory where we felt justified to give it clinical trial, this [illegible] was one of the first to be attacked by direct vision intervention via an incision in the pulmonary artery. Since that time we have had the opportunity to [illegible] on [illegible] patients with pure valvular stenosis. There have been [illegible] in this group. The first five patients have been thoroughly studied [illegible] provide a measure of the effectiveness of the procedure. On the basis of [illegible] of the results obtained in these five patients with [illegible] and the published results of others we feel at the [illegible] transarterial direct vision approach is clearly the operation of choice.

[illegible] TRANSVENTRICULAR VALVULOTOMY

[illegible] all of the data which we have found in the [illegible] our own [illegible] trans[illegible] [illegible] the right [illegible]

TABLE I. Physiologic Observations Before and After Transventricular Pulmonary Valvulotomy

AUTHOR	PREOPERATIVE		POSTOPERATIVE			
	R V PRESSURE	P A PRESSURE	R V PRESSURE	P A PRESSURE	PER CENT REDUCTION R V PRESSURE	RESIDUAL STENOSIS R V P A (SYSTOLIC
Lurie and Shumacker[9]	120/0	2/-2	101/0	3/-2	21.0	98
	65/-7	16/4	39/-5	18/6	74.0	21
	82/-6	46/5	44/-6	26/11	73.0	18
	105/4	46/13	106/0	33/12	-1.0	73
	55/0	19/3	48/6	20/9	28.0	28
	127/-7	5/-8	84/-3	14/4	44.0	70
	142/2	17/5	122/-7	14/5	18.0	108
Bing et al[10]	165/36		135/59		22.0	
	122/30		100/3		24.0	
	84/60		37/14	20/13	87.0	17
	126/40		92/34		35.0	
	145/3	24/9	111/5	35/12	30.0	76
	118/13	22/9	90/10		32.0	
	166/26		72/8	20/9	70.0	52
	128/0	30/17	38/2	26/11	92.0	12
	90/0		98/12		-13.0	
Kirklin[7]	196/5	11/8	65/8	16/12	79.0	49
	55/5	18/10	40/5	20/12	60.0	20
Galligan et al[11]	260/0		60/0		87.0	
	99/11		58/6		59.0	
Humphreys et al[6]	217/9		69/2		79.0	
	162/12		78/12		64.0	
	201/16		77/13		73.0	
	100/0*		40/0*, 77/4		33.0	
Blount et al[12]	200/5	16/20	151/1	22/13	29.0	129
	166/-7	22/13	38/2	25/10	94.0	13
	221/10	18/11	60/6	35/10	84.0	25
	142/-1	13/6	34/-5	14/8	96.0	20
	110/3	16/7	40/2	14/9	88.0	26

*Obtained at the operating table.

preoperative pressure was in fact lowered toward this level postoperatively was observed. The actual lowering compared to the desired lowering is expressed as "per cent reduction." The formula for "per cent reduction," therefore is: Per cent reduction =

$$\frac{\text{Decrease in R. V. systolic pressure}}{\text{Preop. R. V. systolic pressure minus 30 mm. Hg}} \times 100$$

The "residual stenosis" was computed in terms of the postoperative difference between right ventricular systolic pressure and the pulmonary artery systolic pressure. Presumably, if no stenosis at all is present these two systolic pressures will be equal as in the normal individual. Any gradient across the valve must represent stenosis and the magnitude of the gradient may be considered to be a rough measure of the degree of the stenosis. It would be considered that less than 10 mm. Hg gradient would be insignificant, 10 to 40 mm. Hg would be moderate while over 40 mm. Hg would represent significant residual stenosis.

It will be apparent from a glance at Table I, first, that the results obtained are extremely variable; second, that almost one half of the patients failed to received a 50 per cent reduction in their right ventricular hypertension and only one fourth of them received 80 per cent or better, and third that complete or even near complete elimination of pulmonary valvular stenosis is never accomplished.

We feel that this evidence strongly suggests that in the hands of at least several competent cardiac surgeons transventricular valvulotomy fails to accomplish the desired result in many instances. Moreover it is our feeling that although the pulmonary stenosis may have been modified somewhat, patients who have residual right ventricular systolic pressures of 60 to 150 mm. Hg have not been adequately relieved of their disease and do not have a normal prognosis.

EVALUATION OF TRANSARTERIAL DIRECT VISION VALVULOPLASTY

In Table II the data on our first five patients undergoing transarterial valvuloplasty under direct vision are presented. In these patients body temperature was lowered to below 30° C., the circulation entering the heart was temporarily occluded, through an incision in the main pulmonary artery the valve was visualized, and a deliberate plastic reconstruction of the conical deformity was performed.

TABLE II. [illegible] OBSERVATIONS BEFORE AND AFTER TRANSARTERIAL PULMONARY VALVULOPLASTY

[illegible]	[illegible]	[illegible]	POSTOPERATIVE			
			[illegible]	[illegible]	[illegible]	RESIDUAL STENOSIS [illegible] (SYSTOLIC)
[illegible] H	[illegible]	[illegible]	[illegible]	[illegible]	10[illegible]	[illegible]
[illegible]	11[illegible]	1[illegible]	19[illegible]	15[illegible]	110[illegible]	[illegible]
[illegible]	11[illegible]	1[illegible]	[illegible]	[illegible]	[illegible]	0
[illegible]	11	1[illegible]	[illegible]	[illegible]	101[illegible]	[illegible]
[illegible]	11[illegible]		[illegible]	1[illegible]	101[illegible]	1[illegible]

In this table the uniformity of the results, the completeness of the reduction in right ventricular pressure, and the almost complete elimination of [illegible] are apparent. Configuration of pulmonary artery pressure [illegible] return to normal contour (Fig. 1). We feel that [illegible] of the success achieved by this method in [illegible] pulmonary valvular stenosis.

TECHNIQUE

[illegible]

placing four control sutures of 5-0 silk in the wall of the artery, one at each end and one in the middle on each side of the proposed 2 cm. incision. After the clamp has been placed, the incision into the artery can be completed before circulation is occluded. When all is in readiness the tapes on the venae cavae are tensed, cutting off the inflow of blood to the heart. After thirty seconds, a noncrushing clamp is placed across the aorta about 2 cm. distal to its origin, and 0.5 ml. of 1:4,000 Prostigmin is then injected into the aorta between the valve and the clamp, taking fifteen to twenty seconds for the injection. This aortic clamp is now removed. A straight-ended auricular clamp of Harkens is now applied to the very base of the aorta, attempting to occlude the coronary ostia in its grip. An angle toothed ductus or aortic clamp of Potts is now applied to the pulmonary artery distal to the incision in that vessel. The originally placed curved clamp protecting the incision is now removed, allowing entrance into the lumen of the pulmonary artery at approximately one minute after onset of cessation of circulation.

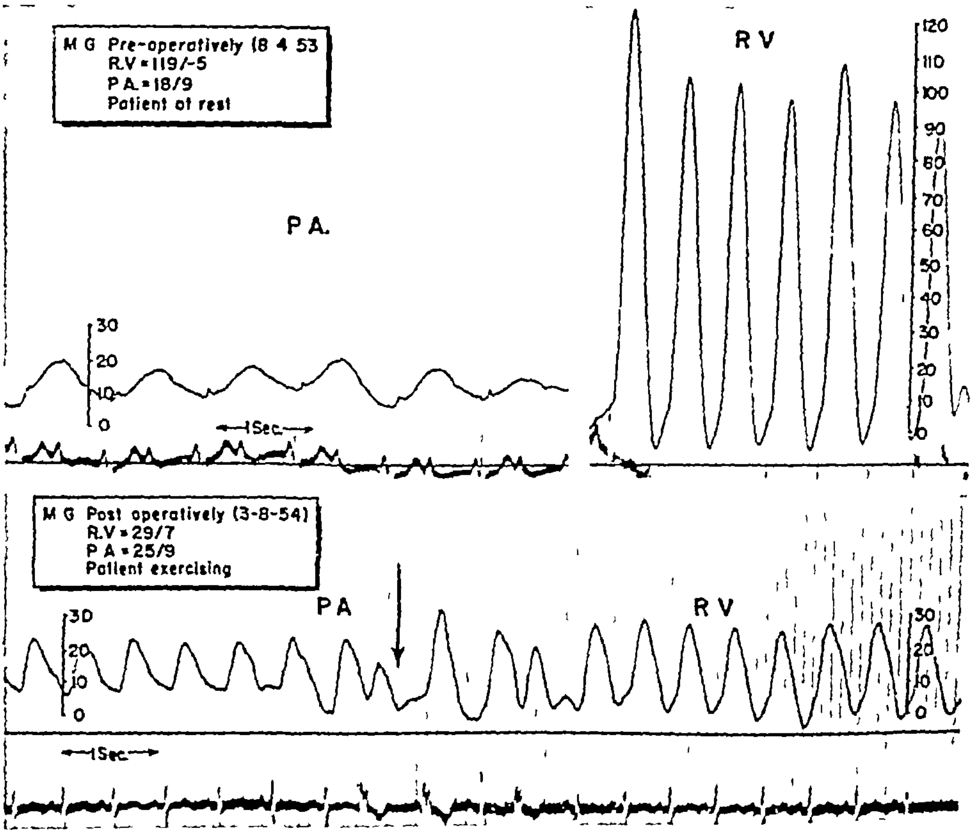

Fig. 1.—Pre- and postoperative recordings of right ventricular and pulmonary artery pressure tracings in patient M. G. Seven months following direct vision pulmonary valvuloplasty pulmonary hemodynamics are essentially normal, even during exercise.

The heart is beating slowly, perhaps 4 to 10 times a minute. The first two or three contractions will serve to empty the right ventricle of blood, from that point on, the operative field is essentially dry. The typical conical valvular deformity lies in clear view. With the tip grasped with toothed forceps, an incision is made with the scissors from the lumen of the valve all the way to the valve ring. If the rim of the lumen is thickened, or if the cone is unduly long, the distal segment of the valve is excised. A [illegible] the first is now made again making sure that the incision extends [illegible] to the ring. The valve now consists of two cusps with complete commissures. [illegible] instrument can and should now be inserted through the valve into the right ventricle to [illegible] the presence of concomitant infundibular stenosis. This entire [illegible] usually relatively simple, can be performed in from one to three [illegible].

[illegible] that the plastic revision of the valve is adequate, withdrawal is accomplished by the following steps. Traction upward is exerted on the four control sutures in the pulmonary artery. The entire chest cavity is flooded with Ringer's solution poured [illegible] certain that the heart is filled and that all air is pumped out through the open pulmonary artery, which is about the uppermost portion of the heart when the patient is lying on his back. The curved toothed clamp is reapplied to the [illegible] if possible under the surface of the Ringer's solution, taking care not to take [illegible] that obstruction to blood flow will occur. The control instruments are [illegible] first the tape on the superior vena cava (to allow blood to mix with the Ringer's solution), then the clamp across the base of the aorta, then the clamp across the pulmonary artery, and finally, after an additional minute or two, the tape on the inferior vena cava. Blood flow is now fully restored.

This entire procedure can usually be performed during three to four minutes of total [illegible] together with an additional minute of inferior vena caval occlusion. [illegible] the heart rate will usually begin to increase as the myocardium [illegible] and the Prostigmin effect gradually wears away.

The [illegible] in the pulmonary artery may now be closed with interrupted sutures of [illegible]. After hemostasis is adequate, routine closure of the thorax follows in [illegible] and the placement of bilateral Pezzar [illegible] pleural drainage through stab wound. We tend to put no [illegible]. If warming of the patient in the tub of warm water is [illegible] used to seal the incision and the finger of a rubber glove is [illegible] the chest tubes with [illegible] glue to avoid the possi[illegible] water into the pleural space around these catheters. [illegible] similar to that of any clean transthoracic procedure.

POSTOPERATIVE CLINICAL OBSERVATIONS

[illegible] examination of the patients revealed some interesting [illegible]. The thrill present preoperatively in the second left intercostal space [illegible] and the harsh systolic murmur decreased markedly in in[illegible]. The [illegible] sound previously decreased or absent was now [illegible]. A [illegible] systolic murmur heard best in the third left intercostal [illegible] in quality, about grade 2 in intensity, could be [illegible] patients.

[illegible] electrocardiograms and x-rays. The former [illegible] right ventricular hypertrophy and in three [illegible] right bundle branch block [illegible] of the [illegible] in all patients [illegible]. This [illegible] occurred [illegible]

DISCUSSION

Isolated pulmonary valvular stenosis is one disease in which precise physiologic data are essential in order to establish properly both the indications for surgery and the results obtained by operation. Objective data secured at operation are unreliable. (See Table I, Humphreys and associates,[6] Case 4, with an operative finding of right ventricular pressure postvalvulotomy of 40/0, whereas later, by catheterization, it was seen actually to be 77/4.) Pre- and postoperative catheterization appears to be essential. On the basis of data obtained in this fashion, transarterial valvuloplasty would seem to achieve complete relief of pulmonary valvular stenosis.

The theory expressed by Kirklin and his colleagues[7] that muscular hypertrophy of the right ventricle may be so great as to cause obstruction to the outflow tract, thus explaining residual postvalvulotomy right ventricular hypertension, is not substantiated by our findings. Although this may occasionally occur, it appears that if the operation on the valve is adequate, the pressure in the right ventricle will promptly fall to normal, as occurred in our five patients. Bing and his co-workers[10] also cast doubt on this theory, since their molds of the lumina of the heart chambers in pure pulmonary valvular stenosis showed no infundibular obstruction due to hypertrophy. The simultaneous occurrence of congenital obstruction in both sites does, of course, occur in rare instances.

The appearance of a diastolic murmur in the pulmonic area in four of these children, we believe, is strong suggestive evidence of the creation of some degree of organic pulmonary valvular insufficiency. In the first three patients operated upon with this method, we made no effort to prevent this eventuality, since on theoretical and experimental considerations we believed that insufficiency of the pulmonary valve (unlike that of all other valves) would be of inconsequential significance. The regurgitant pressure in this instance is that of the diastolic gradient across the valve. In the human being, this might be in the range of 5 to 15 mm Hg, a low pressure indeed. Over a period of several years we had attempted on occasion to create experimental heart failure by radical excision of the pulmonary valve in dogs. Although we kept some of these animals for years no evidence of cardiovascular disturbance appeared. A similar experience was reported to us by Hufnagel.[12] For this reason, in our desire to effectively relieve stenosis we excised considerable portions of the deformed valve in the first few patients. As we have increased our experience however we feel that it is probably possible in many instances to avoid insufficiency by attempting to shape a bicuspid valve which will close adequately. The two cuts completely through the valve together with moderate trimming of the edge, may accomplish this plastic result. In our last three patients the diastolic murmur has been absent or of low intensity.

In the evaluation of all of these patients, the benign nature of pulmonary regurgitation appears to be confirmed. The evidence is as follows. There appears to be no difference in the changes which occur in heart size following the operation whether or not the diastolic murmur is present. The heart diameter by x-ray moderately increases and then stabilizes. Right ventricular hypertrophy decreases as suggested by electrocardiographic evidence. This change occurs following the transventricular repair as well. The greater size probably indicates ventricular readjustment to increased flow. Second, the intensity of the diastolic murmur decreases with time. If intensity parallels insufficiency, readjustments apparently occur which diminish the degree of insufficiency. Third, as will be noted in Table II, the pulmonary valve is still capable of maintaining a diastolic pressure in the pulmonary artery 8 to 9 mm Hg higher than that in the ventricle. These diastolic pressures are essentially normal. Certainly regurgitation is not complete nor apparently even of significant degree.

On the basis of these observations it is our opinion that the relief of stenosis is the primary objective of the operation and should be achieved even at the expense of slight or moderate insufficiency. Insufficiency should not be deliberately disregarded in the plastic repair, but elimination of stenosis by complete incision across the funnel shaped valve is a sine qua non of the procedure.

SUMMARY

1. Seven patients with "pure" pulmonary valvular stenosis with intact ventricular septum have been subjected to pulmonary valvuloplasty under direct vision during hypothermia. All these patients have recovered from the operation.

2. The first five patients have had careful pre- and postoperative physiologic studies. The operation uniformly restores essentially normal hemodynamics.

3. Comparison of these observations with similar studies by ourselves and others of the results of transventricular valvulotomy apparently indicates superiority of the open technique for relief of this congenital valvular anomaly.

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DISCUSSION

(PAPERS BY GLOVER, O'NEILL, GONTIGO, MCAULIFFE, AND WELLS, AND SWAN, CLEVELAND, MUELLER, AND BLOUNT)

DR AARON HIMMELSTEIN, New York, N Y—I should like to discuss this as to the question of the adequacy of the Brock procedure, and would like to show three slides of tracings made in the operating room This 7 year old child was operated upon at the Mt Sinai Hospital, New York

(Slide) These tracings were taken by using a Brock probe that we had made in a hollow form and attached by lead tubing to a recording device Here is a tracing taken before any manipulation of the valve had been done and you can see that the pressure in the pulmonary artery is 10/0, and the rapid transition to right ventricular pressure tracing which is recorded at 135/15 The second lead in the electrocardiogram is here

(Slide) The valve was divided by using the Potts type knife of smaller size, it was passed into the pulmonary artery opened to its largest size, and the valve then was dilated, using the basket dilator, and this recording was made using the same Brock hollow probe Here we see that the pulmonary artery pressure is 25/12, again there is still evidence of stenosis because the right ventricular pressure is 58/16 By our clinical criteria we felt we had done a very adequate operation, and yet here in the operating room we have distinct evidence of the fact that stenosis still is present Therefore the larger sized Potts knife was introduced

(Slide) This tracing was taken after the second size was opened to go through the valve at 18 mm diameter, and here we see that we have lost the evidence of stenosis in this tracing taken by the same technique, the systolic pressure in the right ventricle is now 36 mm Hg, and the peaks in the pulmonary artery are recorded at 53 mm Hg

Our point is that in the first pass we thought we had performed a very adequate operation and in the second pass we proved we had to do a more adequate operation We have no question in our minds that open procedure is preferable to any type of closed procedure if it can be done with the same safety, the same morbidity and mortality as the closed procedure

DR JULIAN JOHNSON, Philadelphia Pa—We, too, have been fairly well satisfied with our patients from a clinical standpoint but have been dissatisfied from the standpoint of the pressure readings which have been obtained Our best results have been in infants or children where the Potts knife is sufficiently large to get a good sized opening Although we have used a 22 *mm* knife in some adults we felt that we had not obtained an adequate opening according to our pressure readings

(Slide) The Potts knife and dilator were not large enough in one particular patient, who was in his 30's so we used the large Bailey aortic dilator and opened it in the pulmonary valve Even under those circumstances and in spite of the fact that we put an index finger down in the ventricle to be sure that we did not have an infundibular [illegible] experience, though we could feel the stenotic valve, it was not opened adequately and the [illegible] pressure was reduced less than 50 per cent. This indicated to us that the valve [illegible] pliability and was pushed aside by the knife which perhaps was not sharp [illegible] dilated by the large aortic dilator only to come back close to its [illegible].

Shall I present an experience with another technique even though it has been [illegible] patient to date because we got phenomenal changes in the murmur and the pressure in the ventricle were reduced to 20 mm. immediately postoperatively and the pressure in the pulmonary artery raised to 25 mm. Hg. I believe one has a better opportunity of cutting the valve entirely back to the wall by using the small guillotine type [illegible] knife.

The knives come in pairs. The right-handed knife may be easily inserted through the ventricle [illegible] the valve engaged by the hooked blade of the guillotine. By pulling [illegible] the hooked end of the knife may be seated at the base of the valve at its [illegible] the [illegible] wall. The guillotine may then be closed, cutting the valve back to [illegible]. The other side of the valve may be cut in the same manner with the left-handed knife.

While I have used it only one time to date, it [illegible] like such a logical method and [illegible] so well that I thought it might be worth while to bring this experience with [illegible] to your attention.

DR. CHARLES P. BAILEY, Philadelphia, Pa.—I had not intended to discuss this [illegible] Dr. Johnson has again proved that great minds tend to run on the same lines. I thought I had better present the work of Dr. Henry Nichols, my associate. He [illegible] thought of the same thing Dr. Johnson did and applied the [illegible] guillotines in an adult with pulmonic stenosis of the [illegible] excellent results so far as pressure reduction was concerned. This [illegible] will be [illegible] the meeting of the American College of Chest Physicians next [illegible].

Dr. [illegible] and I do not have any [illegible] following this procedure. In [illegible] a finger into the heart and [illegible] the two [illegible] of [illegible] cutting [illegible]. The wedge-like point goes up into the [illegible] the valve [illegible] on both sides. As it [illegible] back [illegible] the pulmonary artery wall. I [illegible] what Dr. Johnson [illegible] with the [illegible] shaped [illegible]

[illegible]

One cannot help but be concerned about the extent to which the valve is opened during a blind procedure Time only will tell whether the rather formidable procedure advised and beautifully executed by Dr Swan and his associates is justified on the basis of many factors which cannot be discussed now

The children we have operated upon run and play, ride bicycles, fight, get into trouble, and seem to live normal lives I guess we have made a bad mistake in not catheterizing them

DR EDWARD E AVERY, Chicago, Ill —With Dr Swan's technique of resection of a portion of the pulmonary valve for pulmonary stenosis, we have been concerned about the production of pulmonary insufficiency and its effects All the cases of pulmonary valvular insufficiency that I have been able to find in the literature have been from postmortem findings Because of this, I would like to report one case discovered by cardiac catheterization This 24 year old medical student came in for study because of a loud diastolic pulmonic murmur Catheterization revealed complete pulmonary valvular insufficiency with pressure of about 24/1 in both the pulmonary artery and right ventricle He has been entirely asymptomatic, has had an athletic life, and his electrocardiographic findings are entirely normal

Because of the excellent results that Dr Swan has had with valvular resection, and because we were not set up for hypothermia, we thought that opening the valve in more than one plane might relieve ventricular hypertension even though it might produce some regurgitation In one 31 year old woman we opened the valve with the 22 mm Potts valvulotome to 19 mm in the usual horizontal plane, and then rotated the knife 90° and incised the valve to 19 mm In spite of this two plane incision opening of the valve, her catheterization findings three and one half months postoperatively show her right ventricular pressure to be about 100/10, which is approximately the same as it was preoperatively Clinically, however, she has had an excellent result

I would like to ask Dr Swan to comment on the amount of valvular tissue removed, whether these patients have a diastolic murmur postoperatively, and if he has any other remarks regarding long term effects of pulmonary valvular insufficiency

DR HENRY SWAN, II, Denver, Colo —I should like to thank the discussants for their remarks With regard to the pressure taken at the time of operation, I think the pressures taken in the ventricle and pulmonary artery before any manipulative procedures on the heart are probably reasonably accurate However, after any extensive manipulation has been done, including ventriculotomy, the pressures obtained are often quite unreliable and I think anyone who has taken pressures at the operating table and subsequently compared the pressures with catheterization results has been dismayed at the disparity between the two figures Therefore I do not believe that anything short of careful study at some time postoperatively, when the circulatory dynamics are essentially back to normal, will give the actual situation

I quite agree with Dr Johnson and Dr Bailey that it is highly desirable to cut the valve all the way to the ring It is satisfying to be able to see and to know that you have done so

Dr Avery brings up a most important point that has been worrying us In the first two or three patients I think we may have been enthusiastic in taking out pieces of these valves I am not sure that we ever succeed in achieving a completely competent valve if it is cut all the way to the ring Four of these five patients have Grade 2 diastolic murmurs along the left border of the sternum which were not there before operation

(Slide) This gives some information about the degree of insufficiency in these patients We have dogs now going into their fourth year with the pulmonary valve totally excised I wish to point out that the pulmonary valve is able to hold up a good diastolic pressure in the pulmonary artery The difference between the right ventricle and the pulmonary artery diastolic pressure in these five patients was 8, 8, 10, here 2 and here [illegible]. So in most of the patients the diastolic pressure in the pulmonary artery appears to be holding up.

The clinical observation is that in the electrocardiogram ventricular strain pattern eventually disappears. The heart as shown by x-ray enlarges somewhat within the first two weeks exactly as seen following the Brock procedure; it then stabilizes and we think this represents its adjustment to increased flow. As you once so beautifully stated in a paper, Dr. Holman, the heart and great vessels place themselves in harmony with the blood flow through them. And here we think we have considerably increased the blood flow so the right ventricle actually becomes larger so far as the lumen is concerned although its wall decreases in thickness. We have no experience in the long term follow-up of pulmonary insufficiency, since this is a disease so rare in man.

Dr. Potts: I certainly agree that the clinical results in these patients are very good and you certainly will have helped almost all those children. I hope you will not have occasion to reoperate on too many of them in the years to come.

If you read back far enough you will find that Dr. Potts like Dr. Rienhoff has done almost every operation, and, not only that, he has designed a good instrument with which to do it.

EXPERIENCES IN THE SURGICAL TREATMENT OF AORTIC STENOSIS

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J. FRANCIS DAMMANN, JR., M.D. (BY INVITATION), AND RODNEY T. SMITH, M.D.
(BY INVITATION)
LOS ANGELES, CALIF.

THE importance of developing a method for surgically treating aortic stenosis cannot be overemphasized, because acquired aortic stenosis, resulting from rheumatic heart disease, is the second most common acquired stenotic valvular deformity. Success in the surgical relief of other valvular heart lesions, particularly mitral stenosis, stimulated efforts to devise a method for the surgical treatment of aortic stenosis. Tuffier[1] is credited with the first clinical attempt to relieve aortic stenosis in 1913, but little consideration was given to the investigation of methods for relieving this disorder until the work of Smithy and associates[2] again focused attention on this problem. Smithy investigated the possibility of performing aortic valvulotomy in dogs through a small incision in the aorta immediately above the aortic valve, by means of a sheathed hook knife inserted through the valve cusp. He had no difficulty in incising the valve leaflet, but did have trouble controlling hemorrhage from the friable aorta of the dog because the sutures would tear out. Bailey and associates[3] approached the problem in various ways. They bypassed the valve in the experimental animal by means of an aortic graft from the left ventricle to aorta. However, these grafts thrombosed in the majority of animals. Using a cutting punch they also approached the valve retrogradely by means of the brachiocephalic trunk and through an incision in the left ventricle but uncontrollable regurgitation produced a large number of deaths.

One patient whose valve was incised died immediately of severe aortic regurgitation. They concluded that mechanical dilatation rather than cutting the valve seemed the most favorable method of surgically treating this disease. Although, initially, retrograde dilatation through the carotid artery was thought to be a satisfactory approach, difficulty was encountered later in finding the stenotic orifice of the inverted cone-shaped valve through this

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[illegible] and the investigators began to employ a transventricular approach through an incision in the myocardium of the left ventricle. Brock[4] [illegible] approach the valve retrogradely by passing a cardioscope [illegible] carotid artery through an incision in the neck with the idea of first [illegible] the stenotic orifice and then incising the valve to relieve the stenosis. However, although he could visualize the valve leaflets and the [illegible] he was unable to see the orifice with this instrument. D[illegible] Scott originally attempted to perform a digital commissurotomy of the aortic valve through an incision in the wall of the left ventricle, but the [illegible] hemorrhage and the friable character of the left ventricular myocardium made this method too hazardous. They subsequently used a dilating instrument which they passed through a small incision into the aortic valve. [illegible] associates developed an instrument with parallel dilating bars [illegible] in order to help locate the stenotic orifice employed a lead wire that was first inserted into the ventricle and through the valve orifice so that the dilator would follow. More recently [illegible] they advocated a retrograde approach to the [illegible] by means of a sternum-splitting or right thoracotomy incision by means of suturing a glass pouch to the wall of the aorta, through which the finger [illegible] inserted simultaneously with the dilating instrument to palpate the [illegible] and to guide the instrument into the stenotic orifice. They believe that this approach is the most desirable one in cases of isolated aortic stenosis.

D[illegible] past eighteen months we have operated on a series of [illegible] aortic stenosis using a ventricular approach and employing a [illegible] instrument to open the valve. The results in this group of patients [illegible]

PATHOLOGIC AND PHYSIOLOGIC CONSIDERATIONS

A[illegible] stenosis may be either acquired or congenital. The acquired type [illegible] heart disease and is seen much more fre- [illegible] of the valve leaflets occurs as the [illegible] along with relatively early and [illegible] the valve until fusion or con- [illegible] Congenital aortic stenosis [illegible] the left ventricle by the stenotic valve If the mitral valve is also affected by the rheumatic process, mitral insufficiency is more likely to occur because of the increased left ventricular pressure Over a period of time, left ventricular hypertrophy develops, placing increased demands on the already inadequate coronary blood supply

SELECTION OF CANDIDATES FOR AORTIC VALVULOTOMY

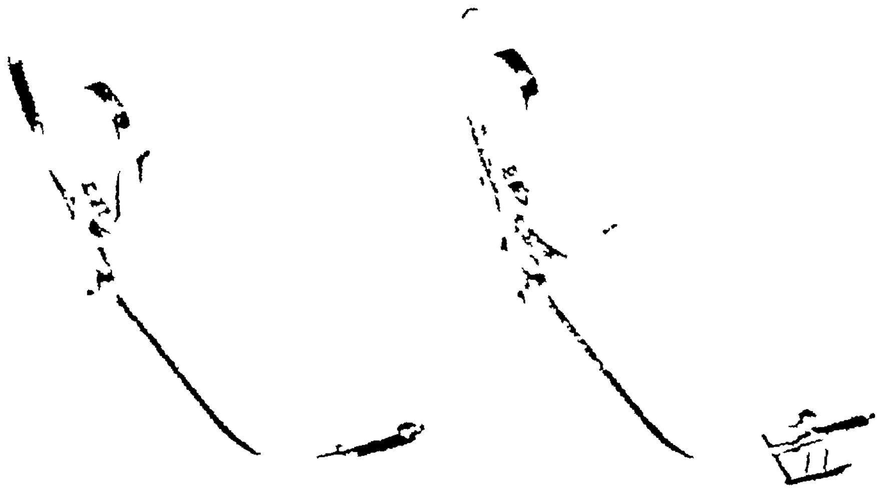
A classification of patients with aortic stenosis, primarily according to the severity of their symptoms, may be of aid in selecting candidates to undergo aortic valvulotomy

Group I Patients with a murmur characteristic of aortic stenosis only
Group II Patients with a murmur, palpitation, easy fatigability, and mild dyspnea
Group III Patients with the more advanced symptoms of dizziness, angina, and syncope
Group IV Those with any of the above symptoms associated with an additional defect, such as mitral stenosis
Group V Those with advanced disease who have congestive failure and peripheral edema, in addition to the symptoms in the other groups

Patients selected as candidates to undergo aortic valvulotomy by present techniques should have relatively pure aortic stenosis If, in addition, a mitral valvular lesion is present, it should be predominately stenotic, although a considerable degree of insufficiency may be present This insufficiency may be greatly decreased if the aortic valve can be opened satisfactorily Many patients with aortic stenosis have diastolic murmurs characteristic of aortic insufficiency However, unless other findings, such as a low diastolic pressure, an excessively enlarged left ventricle and a great intensity of the diastolic aortic murmur itself, are present, the operation should be performed Age, per se, is not necessarily a limiting factor However, patients over the age of 50 or 55 years should be considered very cautiously Patients with congenital aortic or subaortic stenosis should be operated upon when the diagnosis is made, if electrocardiographic and roentgenographic examination give evidence of left ventricular strain and enlargment At present we believe that patients who fall under Groups II, III IV, and V should be considered as candidates for aortic valvulotomy The regimen for those with severe symptoms and evidence of heart failure should consist of digitalis, mercurial diuretics, and bed rest before the operation in order to remove as much excess body fluid as possible The heart size itself will often become much smaller and the lung fields less congested as a result of this treatment It is important to operate on patients with aortic stenosis as early as possible, especially if their symptoms have been severe because, unlike patients with mitral stenosis those with aortic stenosis, after only one or two episodes of failure may develop fatal left ventricular failure One patient who appeared to be in satisfactory condition for operation suddenly died of acute left heart failure the day prior to operation He had just eaten and had felt well until this sudden failure [illegible] There are several contraindications to operation, such as marked [illegible] complete heart block, subacute bacterial endocarditis, evidence of [illegible] low myocardial reserve, acute rheumatic fever, and several others depending upon the individual patient.

TECHNICAL CONSIDERATIONS

In the patients herein reported, the valve was dilated by an instrument (Fig. 1) inserted through a stab wound in the left ventricle. This approach [illegible] because of the simplicity of the operative exposure and ease with which the [illegible] can be entered from the ventricular side. The patient is placed [illegible] on the operating table, and the left side is elevated approximately 20 degrees. Endotracheal anesthesia is used to maintain the patient [illegible] with cyclopropane or Pentothal sodium. The chest is entered through an anterolateral incision in the fifth intercostal space, extending from the border of the sternum to the posterior axillary line. The fifth costal cartilage is [illegible] to the sternum. The pericardium is incised be-



valve (Fig 3) One can easily feel the instrument after it passes into the aorta beyond the stenotic valve which is usually located easily with the leading end of the valvulotome However only mild to moderate force should be employed to pass the instrument through the valve opening With dilatation of the valve one usually feels the sensation of sudden 'giving' as it opens (Fig 4) The heart may become momentarily slow or occasionally more rapid The instrument is withdrawn and the pressures are again

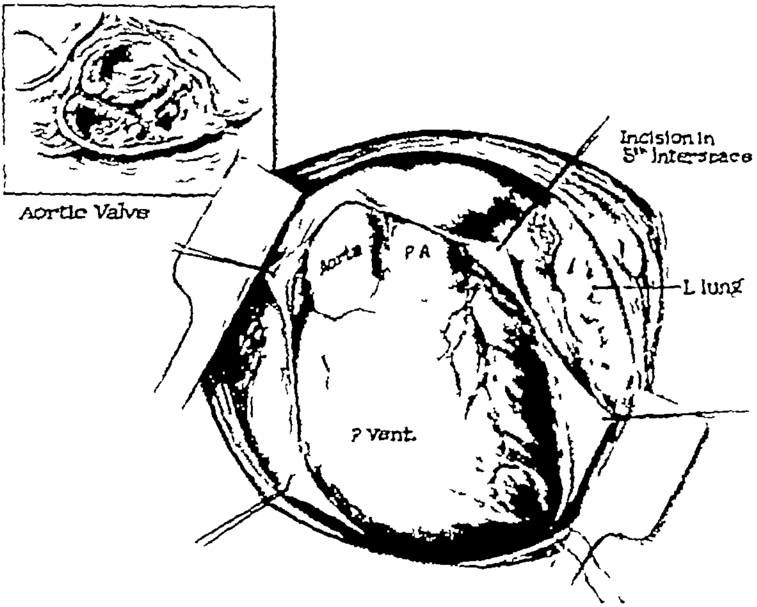
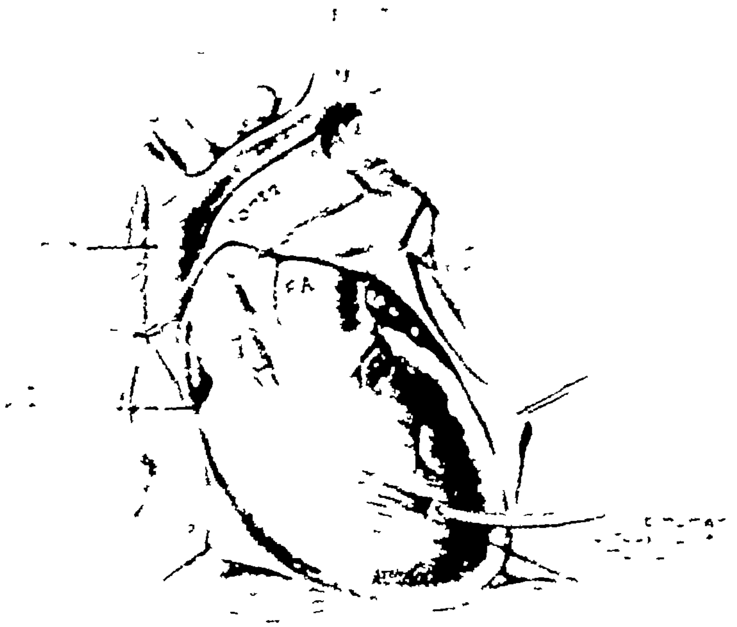


Fig 2 —Drawing of operative exposure through anterior left fifth intercostal space The pericardium has been incised from the apex to the origin of the great vessels A purse string suture has been placed in the left ventricular muscle

measured If there is a satisfactory change in pressures the stab wound is closed with interrupted silk sutures and the purse string is removed If not the valvulotome is again introduced for further dilatation The pericardium is closed loosely with interrupted sutures A small window of pericardium is removed in the posterior inferior aspect to allow dependent drainage Penicillin is placed in the chest cavity and the chest is closed in anatomic layers An intrapleural catheter is attached to water seal drainage

This approach has the disadvantage of producing a wound in the ventricular myocardium thus increasing the likelihood of serious arrhythmias such as ventricular fibrillation In this series we have not encountered this difficulty Another disadvantage is that bleeding from the hypertensive left ventricle may be difficult to control The purse string tore out on three occasions during early operations in this series so we decided to attempt a retrograde approach through the innominate or carotid artery This approach should have the advantages of better control of bleeding and not injuring the wall of the left ventricle We were aware of the difficulties which both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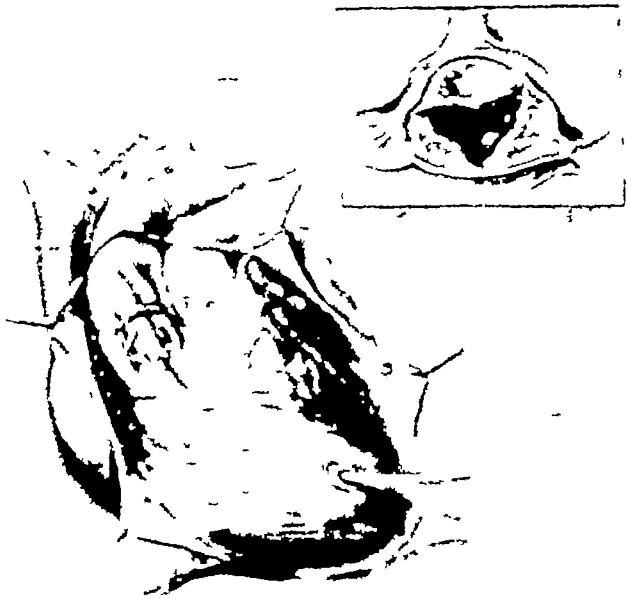


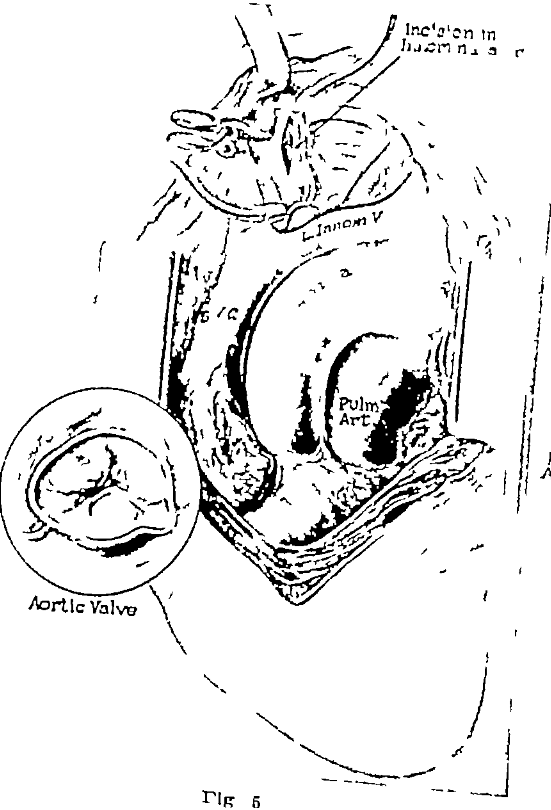


Fig 5

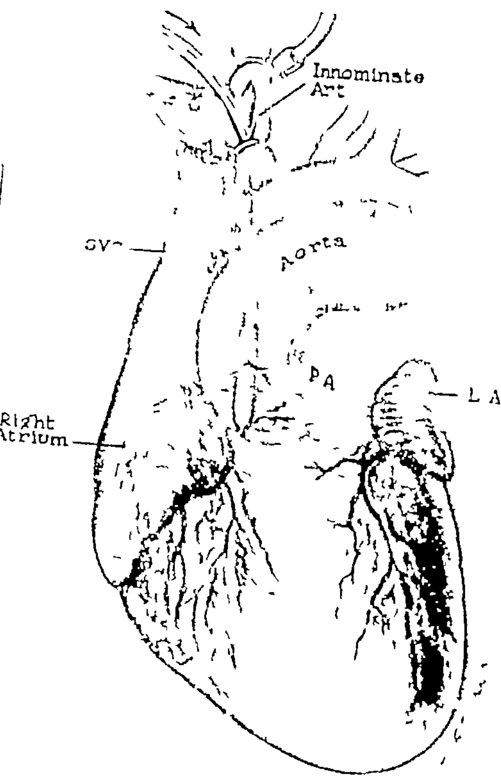


Fig 6

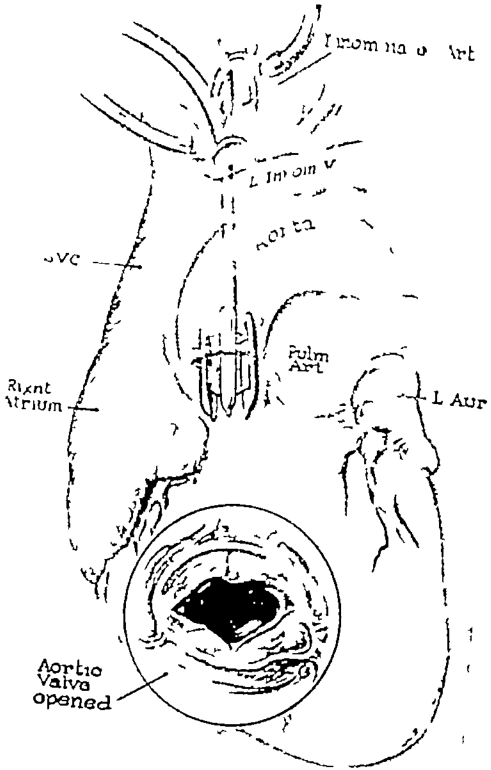


Fig 7

Fig 5 —Exposure of great vessels through median sternotomy incision The innominate and left carotid and subclavian arteries have been isolated nd an incision is made in the carotid and innominate arteries

Fig 6 —The valvulotome has been inserted to the desired level in the aorta through an incision in the innominate artery

Fig 7 —The aortic valve is dilated with the valvulotome from the innominate side of the aorta The inset shows the dilated aortic valv rom the innominate side This procedure did not prove to be feasible in one patient on whom it was attempted

[illegible] and Brock[4] encountered in approaching the valve retrogradely, but thought that exposing the heart through a sternum splitting incision (Fig. 5) and guiding the end of the dilator by palpating the aortic ring externally could allow the valve orifice to be located and entered without great difficulty (Figs. 6 and 7). Such a procedure was attempted on one patient but the small aperture of the cone shaped valve could not be located and the patient expired during the manipulations. Therefore we returned to the ventricular approach and since that time have had no appreciable difficulty using it. It is of great importance to place the mattress suture properly in the ventricular muscle and to emphasize that the assistant should not tighten it excessively but should partially control bleeding by applying pressure with a small gauze sponge on a hemostat at the point of entry into the ventricle.

When mitral stenosis is present, in addition to aortic stenosis, we open both valves in a single stage procedure. Initially we approached dual lesions through a posterolateral incision in the fifth intercostal space. However, these patients tolerated the supine position much more satisfactorily than the lateral one and recently we used a slightly longer anterolateral incision in the fourth intercostal space with division of the fourth and fifth costal cartilages adjacent to the sternum. We originally thought that the aortic valve should be opened first in order to allow better coronary artery filling and also because the concomitant stenotic mitral valve would aid in preventing bleeding from the left ventricle through the ventricular incision by decreasing the amount of blood entering that chamber. However we now believe that the valve which is most significantly involved should be opened first. For example, if the patient's symptoms are primarily those of angina or syncope, the aortic valve should [illegible] opened first. [illegible] they are primarily pulmonary edema, dyspnea and [illegible] the [illegible] should be on the mitral valve.

RESULTS AND DISCUSSION

A total of [illegible] patients were operated upon in this series. Of this total [illegible] had mitral valvular deformities in addition to [illegible] stenosis and [illegible] coarctation of the aorta (Table I) [illegible] (Table II).

[illegible]

Of the group with isolated aortic valvular disease, 6 had pure aortic stenosis and 10 had aortic stenosis and insufficiency, as evidenced by a diastolic murmur along the left sternal border. Only 5 of the 16 gave a history of rheumatic fever. Dyspnea and orthopnea were the predominant symptoms in this group, having occurred in 14 of the patients. Angina was present in 11, and syncope occurred in 7. Eight gave a history of having had previous episodes of heart failure (Table III). Cardiac enlargement, to some degree, was present in all these patients, and was primarily due to left ventricular enlargement. Calcification of the aortic valve was found in 13 of the 16 patients at the time of operation, and was determined by contact of the dilating instrument with the calcified valve. Most of these valves could be visualized fluoroscopically prior to operation.

TABLE II

AGE (YEARS)	AORTIC VALVE DEFORMITY	AORTIC AND MITRAL VALVE DEFORMITY	AORTIC STENOSIS AND COARCTATION OF AORTA
10-20	1	0	0
20-30	1	2	0
30-40	7	2	0
40-50	6	3	1
50-60	0		0
Over 60	1	1	0
Total	16	8	1

In the group of patients with dual deformities, two gave a previous history of rheumatic fever. All histories included dyspnea, and 8 of the 9 noted orthopnea. None experienced syncope, and only 1 had angina (Table III). Seven of the 9, however, had previous episodes of failure, and 4 gave histories of hemoptyses. All of these patients had some degree of cardiac enlargement, and calcified aortic valves were found to be present at the time of operation in 8. Only 1 patient had auricular fibrillation.

TABLE III

	AORTIC VALVE DEFORMITY	AORTIC AND MITRAL VALVE DEFORMITY
Number of cases	16	8
History of rheumatic fever	5	2
Dyspnea	14	8
Orthopnea	14	7
Syncope	7	0
Angina	11	0
Cardiac failure	8	6

There were 4 operative deaths, 2 in the group with aortic disease alone and 2 in the group with dual deformities (Table IV). The oldest patient in the series, a 63-year-old man with aortic stenosis and insufficiency, died during performance of a retrograde procedure through the innominate artery. The small valve orifice could not be located, and sudden irreversible cardiac arrest occurred shortly after the leading end of the dilator reached the region of the valve. A 31-year old man with aortic stenosis and insufficiency died of cardiac failure forty-eight hours postoperatively. Although the valve was widely dilated the instrument upon closing caught a small portion of one of the leaflets between the dilating components and avulsed it, producing severe insufficiency. Immediately following his return to bed the patient developed severe pulmonary edema which could not be adequately controlled by massive phlebotomy and supportive medical treatment. The late death in this group occurred in a 49-year-old man who was judged to have excellent improvement following the operation. However, he received a blow on his head which caused severe cerebral trauma and subsequent death nine months after the operative procedure.

TABLE IV. RESULTS

	SLIGHT IMPROVEMENT	MODERATE IMPROVEMENT	EXCELLENT IMPROVEMENT	OPERATION TOO RECENT	DEATHS	
					OPERATIVE	LATE
[illegible]	1	1	4			
[illegible] and [illegible]		2	3	2	2	1 (Trauma)
Total	1	3	7	2	2	1
[illegible] and mitral [illegible]			1			
[illegible] mitral [illegible] and in[illegible]			2		1	
[illegible] and in[illegible] mitral [illegible] and in[illegible]			1	1	1	1
Total	0	0	4	1	[illegible]	1
[illegible] and [illegible]			1			
Total results	1	[illegible]	1[illegible]	[illegible]	4	[illegible]

In the group with dual lesions one patient, a 42-year-old man, died one [illegible] after operation. He apparently sustained a cerebral embolus during the procedure, was disorientated and exhibited a left hemiparesis of the arm [illegible] when he recovered from the anesthetic. He died suddenly following urethral catheterization. Twenty-four hours after operation a 26-year-old female patient died of a cerebral embolus sustained at the time of operation, [illegible] having regained consciousness. Post-mortem examination showed the valves appeared to have been adequately opened. The late death [illegible] occurred in a 49-year-old man who died of a pulmonary embolus, [illegible] pulmonary congestion and cardiac failure three months after [illegible]. This patient had extreme cardiac enlargement [illegible]. The aortic valve had been opened satisfactorily. [illegible] necessary to dilate the mitral valve retrograde [illegible] the ventricular incision [illegible] small and [illegible] mitral commissurotomy The patient's postoperative course was uneventful and he left the hospital twelve days after operation He was thought considerably improved, because dyspnea and orthopnea disappeared and his exercise tolerance increased

Objective evaluation of these patients is indeed difficult Criteria include changes in pressures (Fig 8) measured in some of these patients during operation changes in heart size (Fig 9) revealed by roentgenographic examination, and increased exercise tolerance However, much of the evidence for determining the degree of improvement has been the patient's statement of the disappearance or relief of such symptoms as easy fatigability palpitation

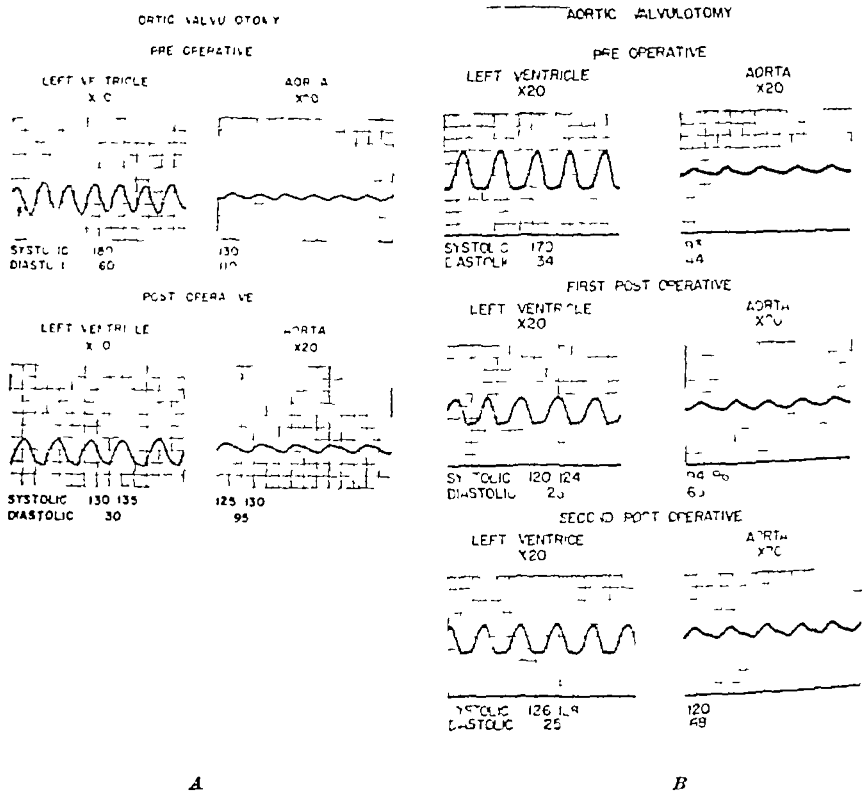
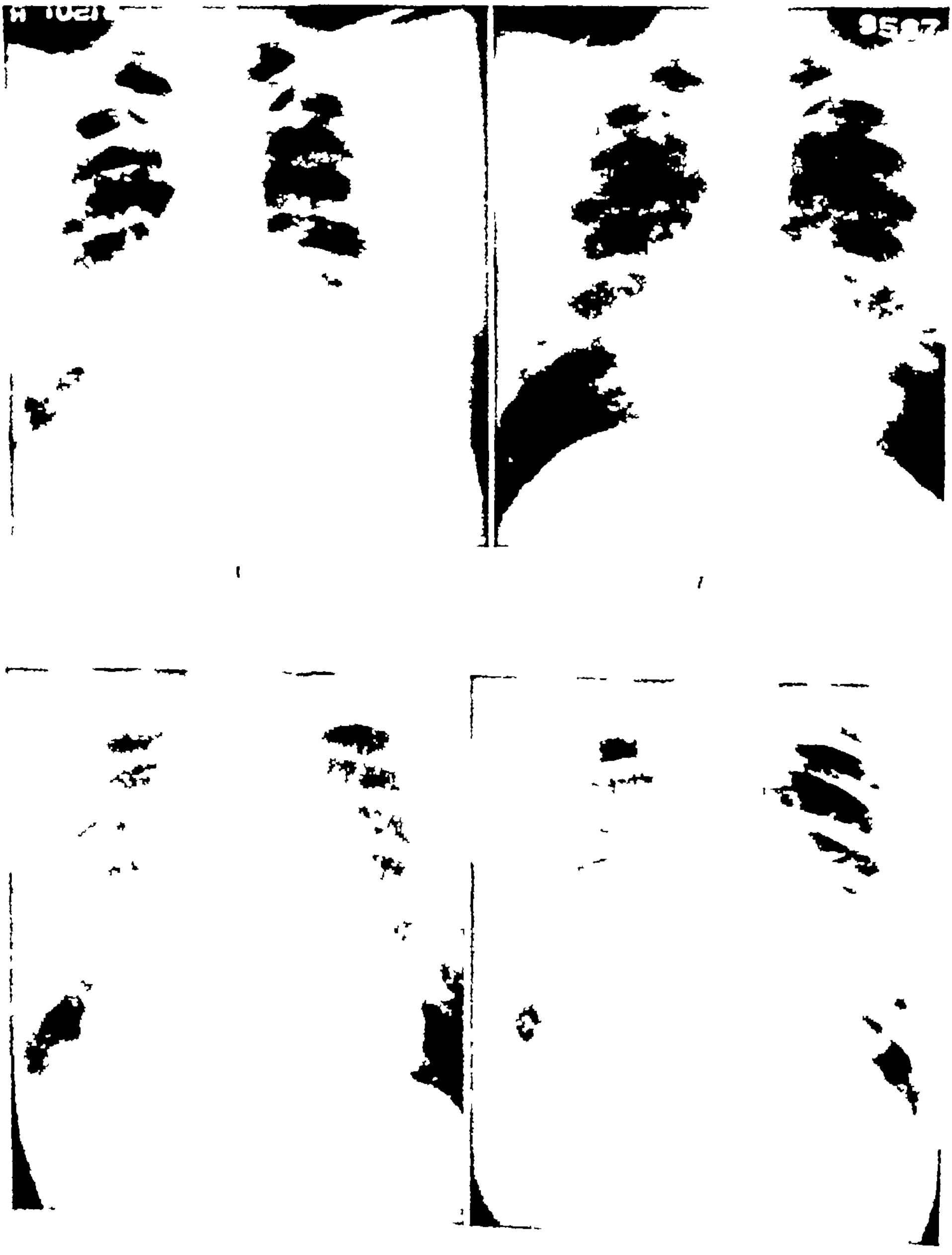


Fig 8—*A* Pressure tracing from left ventricle and aorta of a 14 year old boy before and after valvulotomy The left ventricular pressure is essentially equal to the aortic after the valve is opened *B* Pressure tracings from left ventricle and aorta of 44-year old man before and after valvulotomy The first postoperative tracing shows valve not adequately opened The second postoperative tracing shows the systolic pressure in aorta and left ventricle are essentially equal

exertional dyspnea, and angina, and the patient's ability to resume a gainful occupation In none of the patients has the murmur disappeared In some it has become less intense than prior to operation In several, the diastolic murmur has increased after operation but in none has it become significant Heart size has decreased in some instances, but in others has remained about the same size, in some it has actually become larger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Of the 19 living patients, the longest follow-up period has been for eighteen months and the shortest for two weeks. Three of these patients operated on less than two months ago were not included for evaluation of results. Of those patients with aortic deformities alone, 1 was thought to be slightly improved, 4 showed considerable improvement and 7 were considered to show excellent improvement. Four of those with mitral and aortic deformities showed excellent improvement. The patient with coarctation of the aorta and aortic stenosis was also considered to show excellent improvement (Table IV).

Severe hemorrhage occurred at the time of operation in three patients. In each case the purse-string suture tore out of the ventricular muscle and was controlled by digital occlusion of the opening while a heavy, mattress suture was placed about it and tied loosely. In another the purse string tore out but relatively little bleeding followed. These incidents occurred relatively early in the series and such difficulty has not been encountered since a mattress suture placed deep in the ventricular muscle has been employed with careful manipulation by the assistant controlling it. Cardiac arrest occurred in 5 of the patients, in 4 of whom regular rhythms were restored by means of cardiac massage and administration of drugs. Ventricular fibrillation did not occur in any of the patients. In one patient with aortic stenosis and mitral stenosis and insufficiency, in whom the mitral valve was opened first, a complete heart block took place immediately after the aortic valve was opened. An inherent ventricular rate of approximately 40 began, but cardiac contractions were regular and effective. This rate continued for approximately eight hours, at which time the rate dropped to 20 and the patient became cyanotic and unresponsive. A cardiac pacemaker was employed, whereby electrodes were applied to the chest wall, and contractions were maintained at a rate of approximately 60. The patient became rational and reasonably comfortable immediately. The pacemaker was employed for approximately sixty-four hours. Each time it was discontinued during this period asystole would occur and the patient would become unconscious after about five seconds. Reinitiation of the stimulating current, however, produced a regular rhythm again with restoration of consciousness. Finally, after about sixty hours, a ventricular pacemaker began to take over for approximately five minute periods which gradually became longer until he developed a nodal rhythm. About two days later sinus rhythm was restored and his condition progressively improved. Although he was left with permanent right bundle branch block, he is considered to have achieved one of the best results. Bundle branch block, one right and one left, occurred in two others immediately after their aortic valves were opened but was of no clinical significance. It disappeared in each case after several days. The block in the conduction system in these three patients was probably due either to direct pressure on the atrioventricular node, to the bundle of His itself, or to the production of hemorrhage and edema about these structures. The fact that the changes were reversible seems to confirm this explanation.

In another patient the flexible shaft which manipulates the dilating components of the instrument broke as the valve was being dilated but produced no damage to the heart since it could be easily withdrawn. However the only dilator available was one which was not so satisfactory as the original one and the valve was not opened so widely as desired. It is suggested that because of the complexity of these instruments which makes breakage a possibility an extra dilator be available during the operation.

Another patient, a 44 year old man, was found to have a relatively fresh myocardial infarct near the apex of the left ventricle when the pericardium was opened. He had had no symptoms from it and an electrocardiographic tracing taken immediately after it was discovered failed to demonstrate it. We questioned the advisability of performing the valvulotomy since the infarct was near the desired point of entry through the left ventricle. However it was believed that his chances of recovery would be much better, that the likelihood of his developing a ventricular aneurysm would be diminished and that he would be less apt to have another infarction because of the increased coronary blood flow if the valve could be opened. Therefore a more medial area on the left ventricle was selected as a point of entry and the valvulotomy was performed without difficulty. His postoperative course was uneventful and he has shown considerable improvement.

Although the ultimate results in patients operated on by this technique can be determined only after following them for a long period of time, the early results are encouraging.

SUMMARY

During the past [illegible] years experimental and clinical studies have led to the development of [illegible] procedure for the treatment of aortic valvular disease. [illegible] consists of introducing a [illegible] dilator through [illegible] of the left ventricle and dilating the aortic valve has [illegible] patients. Sixteen [illegible] with aortic deformities [illegible] deformities [illegible] operated [illegible] in this series. There were 2 operative [illegible]. Technical [illegible]

[illegible]

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Discussion

DR CHARLES P BAILEY, Philadelphia, Pa —We have performed a total of 205 operations for aortic stenosis, 11 by a now obsolete technique, 173 by the ventricular route with the standard dilator, and the remaining ones by the transaortic route You will note the greater mortality experienced when these operations were done by the ventricular route than when operated on by the supravalvular approach route In this group of cases you will note that the condition is essentially isolated aortic disease with predominant stenosis and perhaps some insignificant insufficiency You will note that the operative mortality is about 25 per cent, even if we exclude those with dynamic aortic insufficiency In the group in which there was associated mitral disease and in which both valves were operated on simultaneously, the operative mortality was significantly lower (except in true multivalvular conditions), particularly in those with only a combination of aortic stenosis and mitral stenosis Even though this series included all types of cases in various stages of advancement, the high mortality led us to feel that surgery by the transventricular route inherently carried a high risk Approximately 40 per cent of our mortality was due to ventricular fibrillation during surgery

We have operated on 21 cases, and the mortality has been 14 per cent I think that improvement in statistics was due not only to the avoidance of ventricular fibrillation but *also to the avoidance of production of aortic regurgitation This latter complication can* inadvertently be accomplished with the dilating instrument The aorta may be entered by pinching off the aortic wall with the help of a curved Potts toothed clamp or a Satinsky clamp of a special type, and sewing a pouch of pericardium to an opening made in the excluded portion of the aortic wall A purse string suture is placed around the periphery of the patch to maintain hemostasis Then a finger is inserted through the pouch, into the aorta, and into the valve In more than one half of these cases, almost exactly the same percentage as in mitral stenosis, an adequate commissural separation can be obtained by digital pressure, perhaps reinforced by counterpressure with the other hand from the outside of the aorta If necessary, one can slide a mitral guillotine knife along the finger to cut a resistant commissure However, we have devised this instrument which has only two expanding blades, which is worn on the finger for forceful splitting of the commissures

One can follow the expansion of the blades by the finger during the time the valve is being split Then if the third commissure is to be separated, the instrument is turned 120 degrees and is expanded with digital guidance There is one other advantage in operating on these patients from above, that is, if there is coexisting aortic insufficiency or if aortic insufficiency is created inadvertently, it may be treated immediately A threaded probe is passed along the intra aortic finger, and punctures the aortic wall just to the right of the anterior commissure A ball of nylon with a tail is attached to the portion of the suture that comes out of the pouch The ball is drawn into the aortic lumen until the finger tip recognizes its function By this method one can usually cut off all the regurgitation

After completion of the aortic commissurotomy in one case the pressure was 138/68 However, there was a *definite diastolic thrill palpable over the outflow* tract of the left ventricle and the finger could recognize a central gap in the closure of the valve When we put in a ball, the diastolic pressure rose to 90 and the diastolic thrill disappeared

DR ROBERT P GLOVER, Philadelphia Pa —*Of the four cardiac valves with which the cardiovascular surgeon must deal, the aortic valve is and will continue to be, in my* opinion, the most difficult to treat surgically because of its position in the vascular stream [illegible] through the heart. The [illegible] strain and stress [illegible] by the [illegible] patient with aortic stenosis for surgery it [illegible] the *left ventricle* has [illegible] myocardial damage. In this respect it differs from [illegible] mitral stenosis [illegible] the myocardial damage has, for [illegible] left atrium and right heart with a [illegible] cardiac output once the [illegible] are due to failure of [illegible] left ventricle [illegible] A high percentage of mitral [illegible] and right heart) can be [illegible] failure of [illegible] aortic stenosis is fraught [illegible] clinical [illegible]

[illegible] the clinical [illegible] patient with aortic stenosis into five [illegible] Stage I [illegible] Stage II the onset of vague precordial [illegible] palpitation [illegible] heart [illegible] Stage III the development of [illegible] left ventricular myocardium has not [illegible] Stage II [illegible] this time carries a [illegible] mortality [illegible] per cent and a favorable result in almost 75 per cent [illegible] of the left ventricular myocardium has [illegible] Stage IV [illegible] Stage V—frank [illegible] 14 per cent and 57 per cent respectively, and the [illegible] The factor [illegible] of the technique of aortic [illegible] whether performed [illegible]

DR. DWIGHT E. HARKEN, [illegible] Mass. [illegible] thing about [illegible] correction of aortic [illegible] great [illegible]

[illegible] ventricular failure [illegible] does not respond as well to the surgical correction of stenosis Insufficiency cannot be *quantitatively assessed by the diastolic murmur The third syndrome again presents the* same basic qualifying features with the murmur, calcification, left ventricular hypertrophy, and flattening of the brachial tracing Here the enlargement is not so marked as that of the first two syndromes, and the presenting symptom is generally that of angina In this situation something has caused the development of angina before the usual *marked left ventricular hypertrophy has taken place Here coronary insufficiency due to* atherosclerosis is associated with incidental and perhaps insignificant aortic stenosis Two of the 9 deaths in 18 operations for aortic stenosis have been due to coronary occlusion in this group More objective studies at the operating table might have directed our attention to operations that relieve angina without correcting the aortic stenosis, *namely, phenol de epicardialization, poudrage, and pneumonopexy*

A few words about the objective studies in combined and pure stenosis may be in order When a patient with aortic and mitral stenosis is considered for surgery, a brachial tracing is taken If there is no prolongation of the upstroke or total ejection time, we assume that no hemodynamically significant aortic stenosis exists If the ejection and *upstroke time is prolonged, we have to decide whether it is due to block in the aortic valve alteration in peripheral capillary resistance, left ventricular failure or a low* cardiac output Very often this proves that the patient does not need combined aortic and mitral surgery If such a decision cannot be made from clinical evaluation and brachial tracings, we measure the pressure gradient across the aortic valve at the operating table before the mitral stenosis is corrected The gradient is determined by placing needles in the base of the aorta and left ventricle The Sanborn manometer measures pressures, *and these are recorded by the Polyviso writer If this shows that the* gradient is less than 50 mm Hg when there is presumably a good cardiac output, we do not operate on the aortic stenosis Our feeling is that at the present stage in the technique of correcting aortic stenosis, the risk of aortic valvulotomy is greater under these conditions than the potential benefits More than 30 patients have been eliminated from surgical intervention by this technique These patients have been followed for more than four years, and we have no reason yet to regret this decision In other words, *the aortic stenosis has not become clinically significant These patients have been spared* an extra risk that would presumably not have benefited them

A similar type of measurement is also carried out routinely in our operations which is now defined as pure aortic stenosis (the first group of the three syndromes mentioned previously) Such gradients may assess the effect of our correction of stenosis Our valvulotome producing fracture and dilatation, has completely eliminated the gradient in the most favorable cases Ordinarily the gradient is lowered from 80 or 100 mm Hg to *30 or 50 mm Hg*

It is too bad that we have not yet developed really satisfactory techniques for the preoperative evaluation of the degree of aortic stenosis It is also unfortunate that moment to moment determinations of cardiac output are not available Output determinations would give a third dimension that is so important to our present pressure gradients at the operating table I hope that we will soon have these available, and then a great step forward in the objective evaluation will be realized

As to the *possibility of preoperative evaluation of the pressure gradient across the* aortic valve I can only say that retrograde catheterization down the aorta has not been satisfactory We have *however been working with transbronchoscopic left heart* catheterization and have carried it out twelve times without complication As yet we have not been able to control our catheter satisfactorily and have had difficulty in getting it to pass through the needle carrier (which goes from the bronchus into the auricle) into the auricle, then to the ventricle and out through the aorta When we are able to control this catheter in this course we may be able to have a very simple diagnostic test that may spare a large number of patients some very major surgery [illegible] the very worst patients for [illegible] early and late [illegible] substantial [illegible]

[illegible] in the choice [illegible] selection of techniques [illegible] for more [illegible]

[illegible] that there is no ideal treatment [illegible] some [illegible] Our experience is [illegible] of [illegible] patients varying in age from [illegible]

[illegible] valve is through the [illegible] splitting incision exposing [illegible] carefully. The [illegible] on [illegible] the [illegible] of the aortic valve [illegible] The right hand [illegible] without [illegible] dilator through the [illegible] valve opening into the left ventricular [illegible] small in [illegible] The dilator is then opened and [illegible] the opening. The left index finger and [illegible] dilation.

We have [illegible] experience [illegible] of the [illegible] of the [illegible]

[illegible] It can be [illegible] into the [illegible]

[illegible]

DR EDGAR W DAVIS, Washington, D C —I was very much in sympathy yesterday with Dr Ralph Adams, who brought up the problem of what to do for his patient who fibrillated for one hour and fifty minutes I wish now to pose a question about a problem which unfortunately does not allow that amount of time I believe we all realize that the closure of a wound in the left ventricle, made for aortic stenosis, is much more difficult than the closure of any other cardiac incision The muscles are very spongy and friable and sometimes the sutures, when tied just barely tight enough to arrest the spurting of blood, begin to cut through the muscle It is similar to trying to sew together two pieces of cheese Recently we encountered a case like this in which we successfully opened the aortic valve but were unable to close the wound when the instrument was withdrawn Various sizes of suture material were used, with very deep bites taken into the ventricular wall, but the blood continued to flow and the patient died on the table Needless to say, the usual precautions were taken to prevent this bleeding I am wondering if some of the experts can tell me how closure can always be effected

DR CHARLES P BAILEY, Philadelphia, Pa —There are only two answers to the problem of a friable left ventricular wall if you go through the ventricle That is one of the inherent problems in aortic stenosis surgery The ventricle becomes thick and soft and may not hold sutures

One method of suturing has been devised by Dr Ray Rumel, of Salt Lake City, Utah He has developed a clamp which has several prongs on each jaw This is placed in the myocardium on each side of the wound and holds the wound together, giving all the time necessary to place hemostatic mattress sutures However, even that method of suturing fails if the texture of the heart is comparable to a cheese, and a pulsating cheese at that In these latter cases the only way we have been able to stop bleeding is by the use of a suggestion made by Dr Jerome Head, who saw me lose one such patient If two segments of a removed rib are drilled at either extremity one can pass a large threaded curved needle through a hole in one and under the ventricular incision The emerging needle is passed through a hole in the other bone fragment, is returned through the other opening in this fragment, passed through the ventricle under the tamponading finger and finally penetrates the original bone fragment at the opposite end When tied, this amounts to a huge approximating mattress suture, using the bone fragments to convert it into a retention suture In three cases where this technique was applied hemostasis was achieved in each

DR FELIX HUGHES, *Memphis, Tenn* —Dr John Kehne has been doing some work in the Research Laboratory at Kennedy Hospital that might apply in this instance He has taken portions of fascia, excised portions of the aorta of a dog, and has sewn this fascia in as a patch The patch becomes endothelized and smooth, and I am sure it could be used in the aorta In the heart, with the coronary in between, it might not work, but it certainly works in the aorta of dogs Some of these dogs have been followed for six and eight months

DR JULIAN JOHNSON, Philadelphia, *Pa* —It may be that the ventricular wall bleeding which has scared me to death has not been quite as bad as the cases Dr Bailey has had I have not used any ribs but in several instances in which bleeding was severe we have been able to stop it by putting Oxycel gauze under the sutures and tying over it We have had no cause to regret this I have never liked to put foreign material in any wound but we have had at least two, perhaps three cases in which I thought we could not stop the bleeding from the ventricular wound but were able to tie the sutures over the Oxycel gauze

DR WILLIAM H MULLER, Jr (Closing) —I wish to thank all the discussants very much I am not going to try to compare the ventricular approach with the retrograde approach which Dr Bailey has used, having had no experience with the latter There are virtues for both, but in our own hands, we prefer the ventricular approach at

LOBAR AGENESIS OF THE LUNG

CLIFFORD F. STOREY, CAPTAIN (MC) USN, AND
ALBERT G. MARRANGONI, LIEUTENANT (MC) USNR
PORTSMOUTH, VA.

INTEREST in congenital anomalies of the pulmonary system has been heightened in recent years by the striking advances which have been made in thoracic surgical and diagnostic techniques. As a result, lesions of this type are being described with increasing frequency. Lobar agenesis of one lung associated with a congenital abnormality of the remaining bronchial tree on that side is an exceptionally rare developmental defect. This report concerns such a case in which the correct diagnosis was made preoperatively on the basis of the physical findings, chest roentgenograms, bronchoscopy, bronchography, and pulmonary function studies. The diagnosis was confirmed at operation and further verified by histologic study of the resected specimen.

The literature contains reports of only four cases which could be representative of lobar agenesis of the lung. Morton, Klassen, and Baxter[1] reported two cases, one was proved at operation, and the other at necropsy. In each patient there was agenesis of the right upper and middle lobes. Field[2] recorded a case in which the lingula was absent, the left lung small, and the main stem bronchus long and directed posteriorly. Ferguson and Neuhauser[3] described a patient who was found on bronchoscopic examination to have one communicating bronchus to the right upper lobe with an absence of the right middle and lower lobes. The latter two patients were not operated upon, and neither came to autopsy. These cases, therefore, lack definite anatomic proof of lobar agenesis.

CASE REPORT

R. E. H., Reg. No. 1108288, a 21-year-old white man, was admitted to the United States Naval Hospital, St. Albans, New York, on March 1, 1953, complaining of a mild cough, moderate shortness of breath, and a pronounced wheeze over the left chest. Shortness of breath had been present for several years, but it had steadily increased in severity during the previous two years. The wheeze was first noted about two years previously, and had become progressively worse. The patient had had a chronic cough for approximately eighteen months and raised small quantities of fairly thick yellowish sputum. There were *no other complaints*. The *past history* revealed nothing of significance. He had not been hospitalized previously and there had been no serious illnesses, injuries, or operations. His *family history* was not remarkable. General *physical examination* showed normal findings except for the chest. The left hemithorax was definitely diminished in size in comparison with the right. Expansion on the left was markedly decreased. Percussion revealed hyperresonance throughout the entire left chest. The area of cardiac dullness was shifted to the left. On auscultation, it was found that the breath sounds were distant and diminished on the left, and normal on the right.

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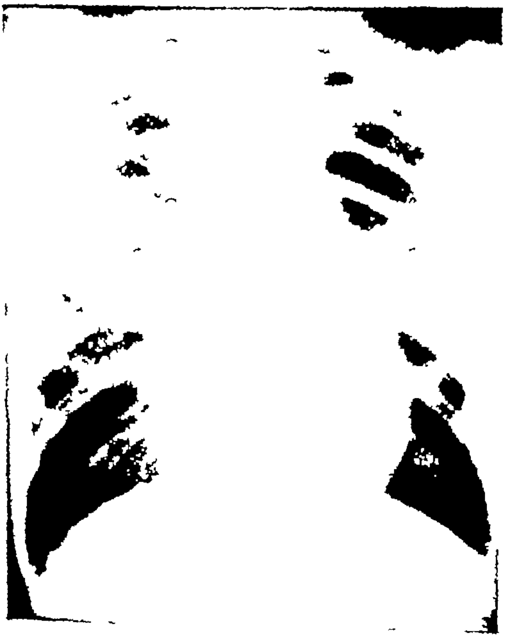
[illegible] that the patient was not moving air well on the left. No rales were present [illegible] on the left. It was most pronounced in the hilar region present [illegible] inspiration and expiration but accentuated on expiration. Chest fluoroscopy showed [illegible] the left lung. There was increased radiolucency of the left lung [illegible]. The right lung appeared normal. The heart was displaced slightly [illegible] left of the normal position. The [illegible] lines in [illegible] shifted rather sharply to the right on [illegible] returned to the left on inspiration, demonstrating trapping of air in the left lung. The [illegible] abnormally radiolucent in all phases of respiration. The bronchogram [illegible] on this side. *Chest roentgenograms*, Fig. 1, verified [illegible] added no additional worthwhile information. *Bronchoscopy* [illegible] trachea. The carina was sharp, vertical, midline and in [illegible] the right bronchial tree. The left main stem [illegible] longer than usual. The normal [illegible] form narrowing on this bronchus [illegible] that its shape was that of a slender elongated cone or [illegible]. The tip of the [illegible] bronchus [illegible] the left stem bronchus and



careful observation *Bronchograms* graphically demonstrated the findings observed at bronchoscopy (Figs 2 and 3) The trachea and right bronchial tree were normal There was marked stenosis of the left stem bronchus with progressively increasing diminution in caliber in a distal direction, so that at its bifurcation, the bronchus was no more than 2 or 3 mm in diameter This bronchus ended in a trifurcation, the most medial branch originating slightly higher than the middle and lateral bronchi, which began at a common level Stereoscopic *frontal (Fig 2), oblique projections (Fig 3), and a true lateral film* showed that the most lateral bronchus coursed upward toward the apex and represented the apical posterior segment of the left upper lobe The middle of the three bronchi passed anteriorly and represented the anterior segmental bronchus There was cylindrical bronchiectasis of this segment The remaining bronchus, the most medial and the highest in origin, was the lingula, and this bronchopulmonary segment filled the lower portion of the left chest, the inferior lingular segment lying posteriorly, and the superior segment anteriorly Despite excellent filling with *contrast medium, no trace of a lower lobe bronchus could be detected*

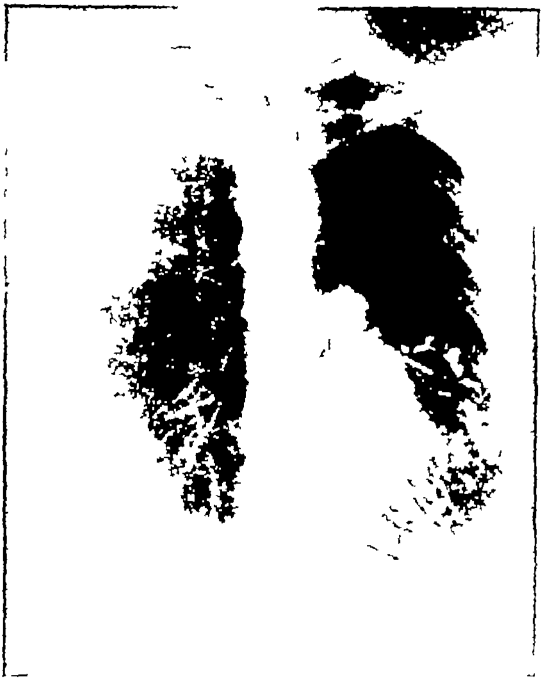


Fig 2—Posteroanterior bronchogram showing stenosis of the left main stem bronchus absence of a lower lobe bronchus and excellent visualization of the three segmental bronchi of the left upper lobe There is marked cylindrical bronchiectasis of the anterior segment of the left upper lobe

Cardiopulmonary function studies revealed the following pertinent findings

Maximum breathing capacity 108 L per minute (74 per cent of predicted)

Timed vital capacity

Total vital capacity—3,200 ml, first second—48 per cent, second second—63 per cent, third second—78 per cent (expected normal percentages 75, 90, and 97 per cent for the first second, and third seconds, respectively)

Bronchospirometric data (normal ranges given in parenthesis)

O_2 uptake—right 86 per cent (52 to 58 per cent), left 14 per cent (42 to 48 per cent), minute ventilation—right 88 per cent (52 to 58 per cent), left 12 per cent (42 to 48 per cent), vital capacity—right 82 per cent (52 to 58 per cent), left 18 per cent (42 to 48 per cent), residual volume 2,150 ml. (181 per cent of predicted) These findings were interpreted as being indicative of obstructive breathing

Cardiac catheterization showed the following pulmonary artery pressures 21/15 and 26/13 on two examinations at rest, the mean pressures being 19 and 18 mm. Hg, respectively On exercise while breathing room air, the pressures were 25/15 (mean 20) and on exercise breathing a low oxygen mixture, they were 32/18 (mean 29) The brachial artery pressures were 106/71 (mean 96) at rest, and 131/80 (mean 101) on exercise The arterial oxygen saturation was 95 per cent at rest, 96 9 per cent on exercise breathing ambient air and 81 2 per cent with exercise plus hypoxia

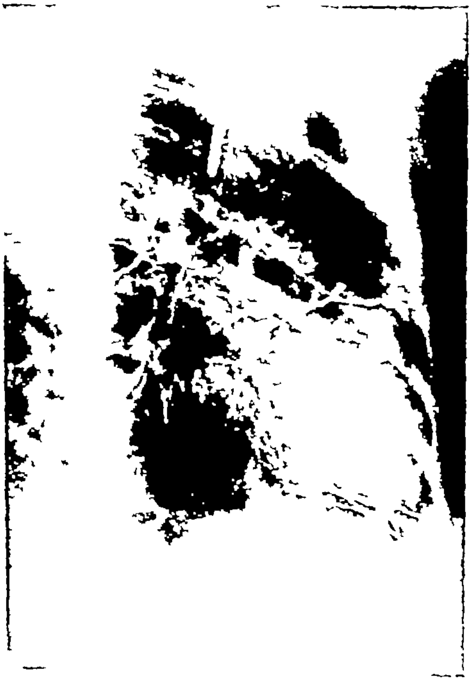


Fig [illegible]—Right anterior oblique bronchogram which shows the stenotic left main stem bronchus to better advantage. The three segmental bronchi are well visualized and the bronchiectasis of the anterior segment is again delineated Note complete absence of lower lobe bronchi

Left thoracotomy was performed on March 19 1953 The preoperative diagnosis was lobar agenesis, left lower lobe, and congenital stenosis, left main stem bronchus When the chest was explored, a completely free pleural space was found An emphysematous left upper lobe showing little anthracotic pigmentation completely filled the left hemithorax. There was no fissure A small meaty structure, about the size and shape of a man s thumb, was attached to the diaphragmatic surface of the left upper lobe This structure was not air containing It was considered to be a vestigial remnant of the left lower lobe The operative plan was to resect the left main stem bronchus and reanastamose that structure at its bifurcation into the upper lobe branches to the trachea at the main carina. Accordingly the anterior pulmonary vein the pulmonary artery, and the left stem bronchus were dissected out the vascular structures retracted, and the bronchus was divided near the main carina proximally and again just proximal to its bifurcation distally The bronchial lumen, which measured 2 to 3 mm. in diameter at its bifurcation, was considered inadequate to permit a

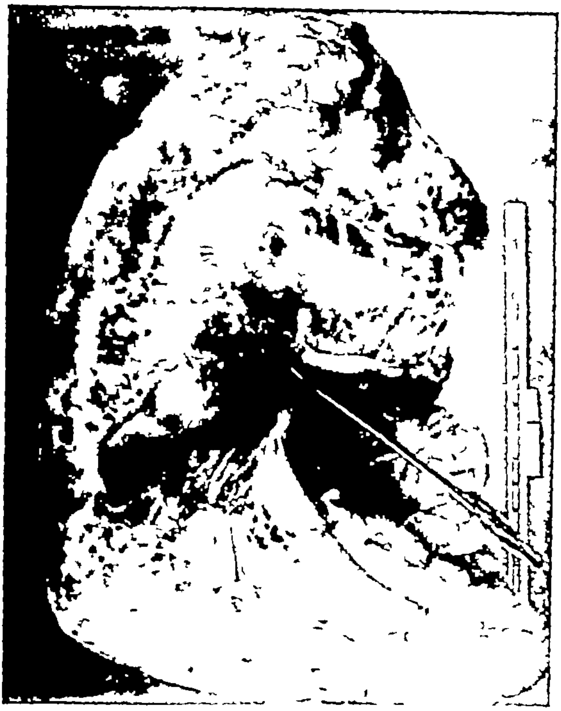


Fig. 4.—Surgical specimen inflated with room air and with the main stem bronchus occluded with a hemostat. The left upper lobe has assumed the configuration of the left lung. The oblong dark area just below and to the left of the center of the specimen is the vestigial remnant of the undeveloped lower lobe. It had no bronchial communication.

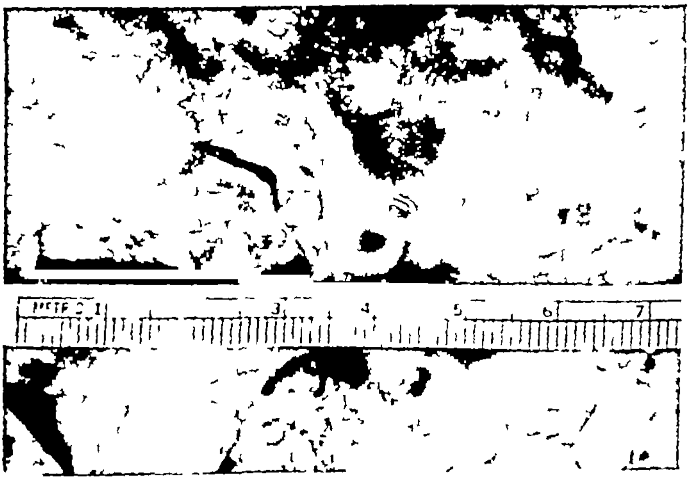


Fig. 5.—End-on view of the left main stem bronchus where it was severed near the main carina. This bronchus measured 4.5 mm. in diameter at its widest point.

satisfactory anastamosis Left pneumonectomy was therefore performed. The inferior pulmonary vein was represented by an atretic, fibrous, cordlike structure. In view of the proved bronchiectasis of the anterior segment the marked emphysema of the left upper lobe, and the very poor pulmonary function on the left, as shown by bronchospirometry, the decision to perform a total resection on the left was probably a wise one, even if resection of the stenotic left stem bronchus with reanastamosis had proved to be technically feasible

Examination of the gross specimen, inflated with room air, showed a left upper lobe the size and shape of a lung (Fig 4) Attached to the base of this lobe was a small sliver of nonair-containing tissue resembling liver substance The left main stem bronchus measured 4.5 mm. in its greatest diameter (Fig 5) Sections of this bronchus showed completely normal histology The upper lobe bronchus gave rise to the usual three segmental bronchi There was no lower lobe bronchus Histologic examination showed bronchiectasis of the anterior segment of the left upper lobe and generalized emphysema.

The patient's postoperative course was uneventful Postoperative pulmonary function studies carried out two weeks after pneumonectomy revealed no significant findings except a reduction in the residual volume to 1,565 ml. (132 per cent of predicted) A seven rib tailoring thoracoplasty was performed on April 9 1953

Pulmonary function studies on May 9, 1953, showed the residual volume to be reduced to 985 ml. (83 per cent of predicted)

Cardiac catheterization at this time showed normal pulmonary artery pressures 18/6 (mean 13) and 18/11 (mean 16) on two examinations at rest 23/10 (mean 19) on exercise breathing room air, and 26/14 (mean 23) on exercise with hypoxia.

Oxygen saturation was 97 6 at rest, 96 4 on exercise breathing ambient air and 80 3 on exercise breathing a low oxygen mixture

Postoperatively, the patient s clinical condition was good The wheeze had disappeared He had no cough or expectoration. His shortness of breath was unchanged

DISCUSSION

The etiology of lobar agenesis appears to be a developmental error of endogenous origin which is closely related to that of agenesis of a lung but has its origin in a correspondingly later period. Arey[4] has described the embryonic development of the respiratory system as beginning with a groovelike evagination, arising on the ventral side of the esophagus in the 3 mm. stage known as the laryngeotracheal groove At the 4 mm stage the two lung buds grow out from the posterior end of this groove Later in the development, the anlage of the trachea and esophagus become separated by a constriction, interrupted at the cephalic end by the larynx, which can be seen in the 5 mm embryo At the 7 mm stage the lung buds give rise to two lateral bronchi on the right and one lateral bronchus on the left The upper end of the right bronchus is destined to be the apical bronchus, the lateral bud to be the axis of the middle lobe and the termination of the main-stem bronchus to be the lower lobe On the left side the lateral bud forms the upper lobe bronchus and the main stem bronchus the lower lobe In later development these hollow evaginations grow out into an envelope of connective tissue enlarge rapidly and branch into a true treelike tubular system On the fine terminal tubules arise small outgrowths which constitute the alveoli This description of development suggests that lobar agenesis occurs between the 5 mm. and 7 mm stage of embryonic development in which there is either complete absence of the lateral buds or of development of the main stem bronchial buds

Most authors have accepted Schneider's classification[5] of agenesis of lung which was established in 1912 as

1 True aplasia of the lung and bronchus in which there is no trace of a bronchus
2 Aplasia of the lung in which the bronchus is represented by a blind pouch or a nodule of cartilage and fibrous tissue
3 Extreme hypoplasia of the lung in which the main bronchus is normal in size and shape and ends in a fleshy structure

The great majority of cases of agenesis of the lung represent post-mortem findings, and the correct diagnosis of this disorder during life is exceptional Garber[6] has suggested that the total of proved cases does not exceed 100 Wexels[7] has recorded eighty-seven cases, of which twenty-eight were diagnosed during life, thirteen of the latter were verified by autopsy, and fifteen of the patients were still alive at the time of his report

The collected literature[8-15] indicates that agenesis of the lung is three times more frequent on the left than on the right It is more common in males than in females in the ratio of 3 2 Most patients with this disease die early in infancy or childhood from either respiratory infection or as a consequence of other congenital anomalies Maier and Gould[16] have suggested vascular compression of the airway by an anomalous course of the pulmonary vessels as the cause of death in some of these cases This group of anomalies does not invariably result in early death Valle and Graham[17] reported a case of agenesis in a 41-year-old woman and have recorded other patients 58, 65, and 72 years of age, respectively, with this developmental defect The large majority of cases reviewed showed various degrees of hypoplasia with little or no functional lung tissue on the affected side

A variety of congenital anomalies have accompanied agenesis of the lung Lucas, Dotter and Steinberg[16] reported a patient who had a patent ductus arteriosus and agenesis of the lung with reversal of the blood flow Other associated defects have been absence of ipsilateral pulmonary vessels, absence of the diaphragm, anal stricture, tracheoesophageal fistula, accessory thymus, hypertrophic thymus, diaphragmatic hernia, absence of a vagus nerve, cleft palate, agenesis of the spleen, kidney, and ureter, esophageal atresia, other cardiovascular anomalies, hypoplasia of the face, and incomplete lobulation of the remaining lung In some instances, three bronchi were supplying a unilobar lung

SUMMARY

Although developmental anomalies of the respiratory apparatus are not exceedingly uncommon, lobar agenesis of the lung is a rare lesion A case of agenesis of the left lower lobe and congenital stenosis of the left main stem bronchus is reported here This appears to be the third such case to be anatomically proved, the second to be confirmed at operation, and the first in which the correct diagnosis was established preoperatively These interesting anomalies are clinically unimportant unless they give rise to symptoms or cause functional deficits When either of these situations prevails, surgical treatment is usually indicated While it was not feasible in the case reported herein, reconstructive surgery may be possible in some patients with this or a similar type of defect

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A SIMPLE METHOD FOR DOING A THORACENTESIS USING A PLASMA-COLLECTING VACUUM BOTTLE

HORACE A. ALBERTSON, M.D., DANIEL LEAVITT, M.D., AND JOHN R. GAMBLE, M.D.
ROANOKE, VA.

IN 1951 Beech wrote an article advocating the use of the blood donor set as a practical system for thoracentesis. We have found his method a highly effective one for removal of pleural effusions. We have only modified the method slightly. Because of its extreme simplicity, we believe that it should once again be brought to the attention of those who may have missed Beech's original article.

Beech used the 600 c.c. vacuum flask, tubing, and needles that are used for obtaining donor blood. Because of its inexpensiveness and size we have utilized the 1,000 c.c. vacuum bottle ordinarily used in the collection of plasma containing no citrate or anticoagulant,* plus a plastic disposable blood donor set. This donor set has a needle 1½ inches long to be inserted into the pleural cavity (Fig. 1.). In the great majority of patients a needle of this length is quite sufficient. If, due to thickness of the chest wall, a needle of greater length is needed, then a very simple arrangement using two glass needle adapters attached to a section of fairly stiff rubber tubing can be sterilized and needles for any desired length used. In the rare case in which this is necessary, one must use considerable caution in inserting the needle attached to the glass needle adapter into the vacuum bottle. This is best done by holding the needle near its hub rather than holding the glass needle adapter. It is rare, though, that the thickness of the chest wall exceeds 1½ inches, and it has been our experience that this is a good safeguard and will prevent one from probing too deep into the chest and damaging the underlying lung tissue.

Thoracentesis, as we perform it, consists of preparing the chest with an antiseptic and inserting a small amount of Novocain under the skin. Next, the tubing is clamped with a hemostat and one of the needles is inserted through the hard rubber cap of the flask. The other needle is inserted through the anesthetized skin via an intercostal space to just inside the pleural cavity. The speed of removal of the fluid is easily controlled by opening and closing the hemostat.

DISCUSSION

The method has many advantages. It is relatively simple. It does not necessitate the wearing of gloves or the preparation of an elaborate tray. The difficulties often encountered with a leaky stopcock and the resultant pneumothorax are avoided. The fluid that is aspirated is collected under sterile technique and is easily transported to the laboratory for bacteriologic and cellular studies. Our pathologist has found no destruction of cells caused by

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From the Department of Surgery, Jefferson Hospital, Roanoke, Va.

Received for publication April 10, 1954.

*Prepared and sold by Baxter Laboratories, Inc.

the collection In fact, he feels that the fluid arrives in the laboratory in better condition than by the routine method of thoracentesis If, after aspiration of the fluid an antibiotic is to be injected into the pleural cavity, it is a simple matter to clamp the tubing near the chest, clean a section of this tubing with an antiseptic and insert penicillin and streptomycin into the pleural cavity by injecting the drug into the tubing

The 1,000 c c vacuum bottle is useful not only because it is inexpensive, but because it serves to remind the house staff that this is the maximum amount that usually should be removed at one time from the pleural cavity

This same apparatus has been used successfully on a number of occasions for performing a paracentesis abdominis and is the method preferred by a number of our house staff

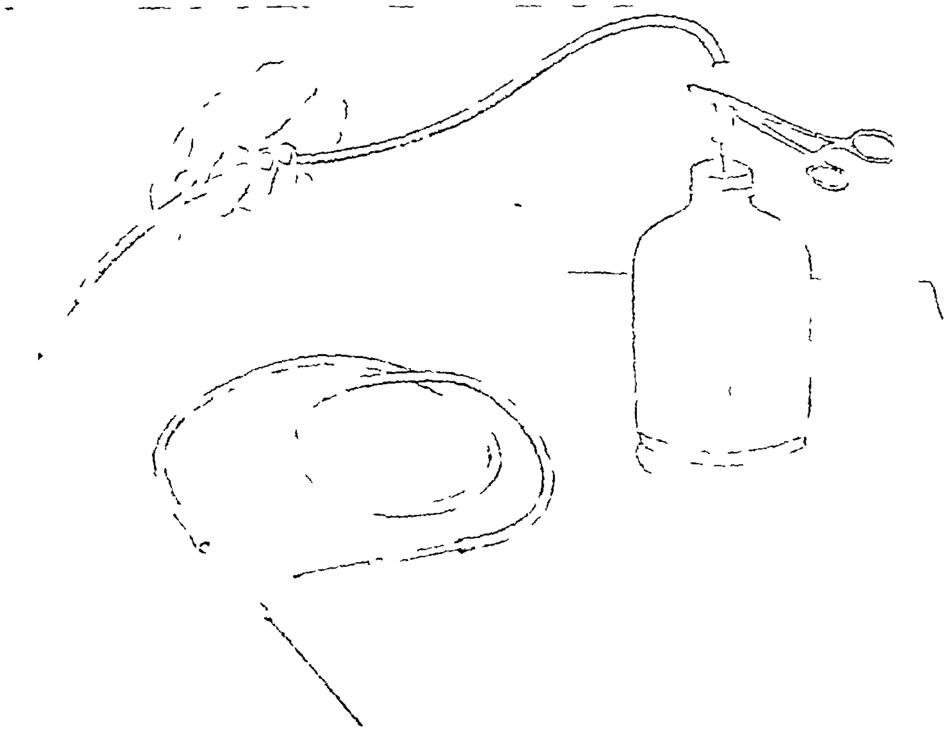


Fig 1 —The usual donor set tubing is connected to the plasma collecting bottle The other unit consists of fairly heavy rubber tubing plus two needle adapters and needles of desired length

This is not as satisfactory to use as the donor tubing

CONCLUSION

We have re emphasized a simple method for doing a thoracentesis using a sterile plasma collecting vacuum bottle and a blood donor set The apparatus is also useful in performing a paracentesis abdominis

REFERENCE

1 Beech B. D Practical System for Thoracentesis Using Blood Donor Set, J A M A 146 1597, 1951

A NEONATAL THORACOTOMY RETRACTOR

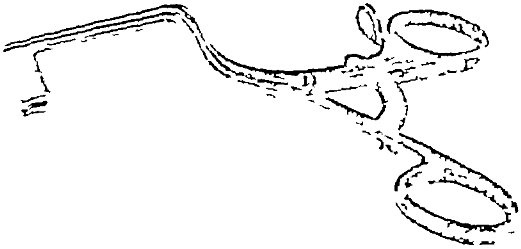
C F A Cummins
Cambridge, England

THE incidence of congenital atresia of the esophagus has been put at 4 in 10,000* but the increasing recognition of this condition suggests that the figure is in fact much higher

Most thoracic surgical units of any size deal with a number of these cases each year and the surgical treatment of these now encourages improved technical aids

A thoracotomy incision in the average newborn infant is seldom more than 2½ by 2 inches and the number of long suture ends disposed around the wound during the anastomosis necessitate a retractor which lies well clear of the operative field, but nevertheless is sufficiently small and strong to give adequate retraction with minimal obstruction to view

Fig 1



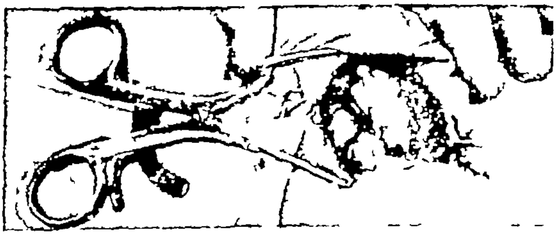


Fig 2

The following description of this instrument has been provided by Allen & Hanbury's, Ltd, who made it to my specification and from whom it can be obtained

> A specially designed stainless steel, cranked, self retaining rib retractor, fitted with two slightly lipped blades $1\frac{3}{16}$ inch deep and $\frac{7}{16}$ inch wide Maximum opening of blades $3\frac{3}{4}$ inches Total length of retractor $6\frac{3}{4}$ inches

I would like to thank Mr C Parish, Consultant Thoracic Surgeon, for his advice and encouragement and Miss Westaby of the Medical Photographic Department at Addenbrooke's Hospital for the photographs

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From the Regional Thoracic Surgical Unit, Nelson Langermann Hospital Papworth Cambridge England

Received for publication July 2[illegible] 1954

*Franklin R H Congenital Atresia of the Oesophagus Lancet 2 243 1947

In Memoriam

John Alexander

1891-1954

Notable among the pioneers who have led in the advancement of thoracic surgery was Dr John Alexander Professor of Surgery at the University of Michigan whose death occurred on July 16, 1954. The span of his interests in thoracic surgery to which his life was steadfastly dedicated saw it develop from humble beginnings in the early twenties to the full-fledged specialty which it is today His devotion to thoracic surgery and his remarkable accomplishments in the face of recurring illnesses were an inspiration to all who knew him

Dr Alexander was born in Philadelphia on Feb 24 1891, the son of Mrs Mazie Just Alexander and Lucien Hugh Alexander, a prominent lawyer of that city His preparatory studies at Episcopal and Chestnut Hill Academies were followed by his enrollment in the University of Pennsylvania, where he received the degrees of Bachelor of Science (1912) Master of Arts (1913) and Doctor of Medicine (1916) He was a member of the varsity crew for four years and its captain during his freshman year in the Medical School Shortly following his graduation he enlisted in an American Unit of the French Army which had been formed by Dr Joseph A Blake With the entry of the United States into World War I he transferred to the Medical Corps of the United States Army After the cessation of hostilities he studied at the Universite de Lyon where he received a certificate in Surgery and Anatomy in 1919 During this time he had the opportunity of studying with Berard who at that time was applying surgical methods for the treatment of pulmonary tuberculosis Following his return to this country he served for a brief period as Assistant to the Professor of Clinical Surgery at the University of Pennsylvania

In 1920 Dr Alexander became a member of the staff of the Surgery Department of the University of Michigan Several months thereafter he developed a pleural effusion and later a complicating Pott s disease which necessitated a protracted period of rest in Saranac Lake New York Perhaps no more stimulating example of devotion to medical science and a will to overcome adversity can be shown than in his writing of the first English text on the surgical treatment of pulmonary tuberculosis The need for a plaster body cast and the support of a Bradford frame were not deterrents Not to be overcome by these physical handicaps he developed a specially designed support for books which could hold them above his head for greater convenience After two years there emerged the *Surgery of Pulmonary Tuberculosis,* for which he received the 1925 quinquennial Samuel D Gross Prize of the Philadelphia Academy of Surgery This volume was dedicated to the belief that thousands of lives would be lost if surgery were not undertaken for patients with pulmonary tuberculosis His prophesies were fulfilled by the rapid development of an era of surgical therapy which became an example to the world at large

John Alexander
(1891 1954)

On recovery from his illness Dr Alexander returned to the University of Michigan in 1926 and continued with general and thoracic surgery until in 1928 the number of thoracic surgery patients had increased sufficiently to warrant his full-time preoccupation with this specialty His first resident in thoracic surgery was appointed in the same year In 1932 the residency program was augmented to a two year plan and his trainees numbering 79 at the time of his death were a continuing source of pride and satisfaction

So rapid were the changes in the surgical treatment of pulmonary tuberculosis in the early thirties and so great became the need for a completely new authoritative text that Dr Alexander again presented the subject in the comprehensive surgical classic *The Collapse Therapy of Pulmonary Tuberculosis,* which appeared in 1937 Although he is particularly well known for his writings on the subject of pulmonary tuberculosis, Dr. Alexander was instrumental in popularizing the two-stage technique for lobectomy for bronchiectasis at a time when the mortality of lobectomy was almost prohibitive. Using this technique he was able to report the first sizable series of lobectomy cases in America with the then low mortality of 16 per cent. More recently he demonstrated the effectiveness of resection of pulmonary metastases. In the field of cardiovascular diseases his observations on localized stimulation of the exposed human heart led to a reversal in terminology of right and left bundle branch block. He was the first surgeon to resect an aneurysm of the thoracic aorta successfully.

Dr. Alexander was a member of the American Association for Thoracic Surgery and was elected its president in 1935. He was also a member of the American Surgical Association, the Central Surgical Association, the International Society of Surgery, the Society for Clinical Surgery, the American Medical Association, the Michigan State Medical Society, the National Tuberculosis Association, of which he has been a director and vice president, and the American Trudeau Society, of which he was president-elect in 1947, an honor which he had to relinquish because of a recurrence of illness. He was a founder member of the American Board of Surgery and the Board of Thoracic Surgery, a member of the Editorial Boards of the JOURNAL OF THORACIC SURGERY and the *International Abstracts of Surgery*, an honorary member of the Sociedad de Argentina de Cirujanos, Société Belge de Chirurgie, Société Française de la Tuberculose, Sociedad Paraguaya de Tisiologia, and the Sociedad Ecuatoriana de Tisiologia. He was a member of Delta Tau Delta, Nu Sigma Nu, Alpha Omega Alpha, Sigma Xi, and Phi Kappa Phi. Among the awards which Dr. Alexander received were the honorary degree of Doctor of Science conferred upon him by the University of Pennsylvania, the Trudeau Medal of the National Tuberculosis Association, the Bruce H. Douglas Award of the Michigan Trudeau Society, and the Henry Russel Award and the Henry Russel Lectureship of the University of Michigan.

Dr. Alexander was a brilliant scholar and inspiring teacher. His courage, cheerfulness, and optimism in the face of recurring illnesses were a source of wonderment and admiration to his many friends. In his later years his love for the outdoors was evident in his hobbies of gardening and duck hunting which he shared with his wife, the former Emma Ward Woolfolk, to whom he was married in 1936. Although thoracic surgery has lost one of its greatest pioneers, John Alexander will long be remembered by his many friends and students and his noteworthy contributions to thoracic surgery will remain a lasting tribute to his memory.

Cameron Haight

Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty fifth Annual Meeting of the American Association for Thoracic Surgery will be held April 24, 25, and 26, 1955, in Atlantic City New Jersey Headquarters will be at the Chalfonte Haddon Hall

Requests for Hotel Reservations

These should be mailed directly to Miss Doris Sears, Convention Manager, Chalfonte Haddon Hall, Atlantic City, New Jersey Please mention this Association, the type of accommodation desired, date and approximate hour of arrival If accommodations are desired elsewhere in Atlantic City, please communicate directly with the hotel of your choice

Thoracic Surgical Forum

By vote of the membership, the Forum is to be continued for the presentation of short papers on current thoracic research, experimental problems, anatomical studies and modified or new surgical techniques The inclusion of any considerable amount of clinical *material in these reports makes the choice more difficult and the Program Committee re*serves the right to reject such papers or to suggest their transferral to the regular program Papers at this session will be limited sharply to ten minutes, including the showing of lantern slides or other illustrative material At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper

These papers will be published together in one issue in the JOURNAL OF THORACIC SURGERY Maximum length 3,000 words without illustrations If illustrated, an appropriate number of words must be subtracted for each cut used

Abstracts for Papers

Abstracts for the presentation of papers at the 1955 meeting, including papers before the Forum, must be received on or before Dec 15, 1954, otherwise they will not be considered by the Program Committee

Abstracts should be labeled "For Thoracic Surgical Forum," or "For Regular Program"

Five, repeat, five copies of each abstract must be sent to the Secretary of the Association, Dr Paul C Samson, 3959 Happy Valley Road, Lafayette, California They should not be sent to the Editor

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec 15, 1954, otherwise, the applications will be deferred for consideration until 1956

Applicants must be sponsored by *three Active or Senior members* of the Association In addition to the signatures on the application form, the sponsors must forward a *separate* letter concerning the applicant directly to Dr Lyman A Brewer, III, Chairman of the Membership Committee, 2010 Wilshire Blvd , Los Angeles 5, Calif

Completed application forms and the sponsoring letters *independently* sent by the three sponsors must be received by Dr Brewer not later than Dec 15, 1954, to be considered for action in Atlantic City

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year

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Original Communications

THE SURGICAL CORRECTION OF MITRAL INSUFFICIENCY BY THE USE OF PERICARDIAL GRAFTS

CHARLES P BAILEY, M D,* WILLIAM L JAMISON, M.D ** (BY INVITATION), ALVIN E BAKST, M.D *** (BY INVITATION), HOUCK E BOLTON, M D ** (BY INVITATION), HENRY T NICHOLS M.D ** (BY INVITATION), AND W GEMEINHARDT, M Sc (M E)**** (BY INVITATION)
PHILADELPHIA, PA

MITRAL regurgitation or insufficiency has long been recognized as a common accompaniment of mitral stenosis Indeed, until it became possible to examine the mitral valve digitally during life, it was generally believed by internists and pathologists alike that mitral insufficiency coexisted in every valve with significant mitral stenosis The inaccuracy of this concept has been pointed out in previous writings[1-3] and is now generally recognized In 984 consecutive patients who have been operated upon by the authors in two Philadelphia hospitals for mitral valve disease, there were found to be 635 (64.5 per cent) cases with pure mitral stenosis, 56 (5.7 per cent) with pure mitral insufficiency 176 (17.9 per cent) with predominant mitral stenosis and insignificant mitral insufficiency 69 (7.0 per cent) in which both the mitral stenosis and insufficiency were of approximately equal physiologic significance and 48 (4.9 per cent) cases with significant insufficiency and insignificant stenosis

In our total experience we have recognized 441 instances of mitral regurgitation great or small, during intracardiac surgical exploration While the majority of these leaks were small and of negligible clinical significance it soon became evident that well developed mitral regurgitation is a much more serious

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From the Division of Surgery of Hahnemann Medical College and Hospital The Department of Surgery of Doctors Hospital Inc and The Bailey Thoracic Clinic Philadelphia Pa

This work was supported by The Mary Bailey Foundation for Heart and Great Vessel Research by The National Council of Brith Sholom Women and by The U S Public Health Grant #H 394

Read at the Thirty-fourth Annual Meeting of The American Association for Thoracic Surgery at Montreal Quebec May 3-5 1954

*Professor and Head Department of Thoracic Surgery Hahnemann Medical College and Hospital Attending Thoracic Surgeon Doctors Hospital Inc Philadelphia Pa and Abington Memorial Hospital Abington Pa Director The Bailey Thoracic Clinic Philadelphia Pa

**Junior Attending Thoracic Surgeon and Instructor Department of Thoracic Surgery Hahnemann Medical College and Hospital Thoracic Surgeon The Bailey Thoracic Clinic, Philadelphia Pa

***Resident Department of Thoracic Surgery Hahnemann Medical College and Hospital Philadelphia Pa

****Research Engineer The Mary Bailey Foundation Philadelphia Pa lesion than mitral stenosis Indeed, we feel that clinically it is at least equal to marked aortic insufficiency in its effect upon the integrity of the circulatory system

Strangely, the profession has been extremely slow to recognize this Usually, mitral insufficiency has been considered relatively benign However, White[4] clearly points out its seriousness in his textbook Probably a part of this lack of understanding has been based upon the presumption that most apical systolic murmurs are indicative of mitral incompetence Actually, significant mitral regurgitation may be present or absent regardless of a systolic murmur Furthermore, a small leak may cause as loud a murmur as a large one Undoubtedly, MacKenzie's teaching[5] that the existence of a specific type of valve lesion was unimportant in comparison with the health of the cardiac muscle has, in the past, seemed to lessen the importance of differentiating mitral stenosis from regurgitation This concept probably had practical clinical advantages at a period when surgical repair of deformed valves was unthinkable Now, however, the time has come to discard outmoded and dogmatic *pronunciamentos*

Actually, the effects of a major mitral regurgitation upon the circulation are most profound and serious The pulmonary vascular bed becomes congested and hypertensive much as in severe mitral stenosis Simultaneously, the left atrium becomes dilated, often to a greater degree than in mitral stenosis, and the right ventricle undergoes comparable dilatation and hypertrophy and eventually fails The usual phenomena associated with such right-sided heart failure are then observed (hepatomegaly, ascites, systemic venous distention, dependent edema, pleural effusion, etc)

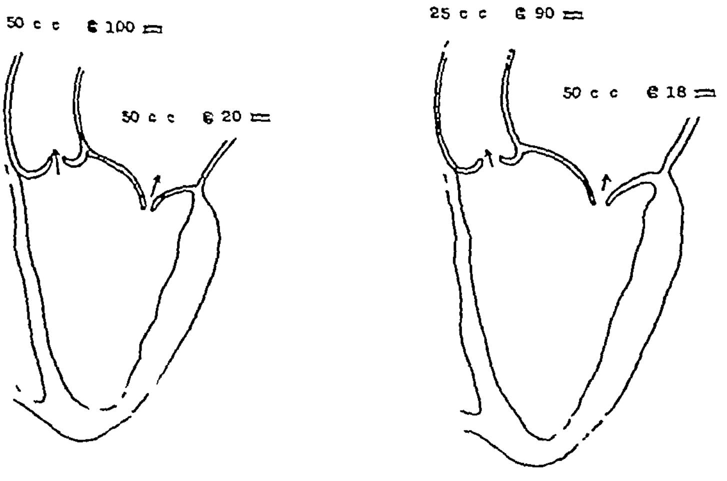
Unlike the condition encountered in mitral stenosis in which the left ventricle remains small and relatively healthy, protected by the mitral obstruction from overfilling and hence from overwork, in significant mitral insufficiency the left ventricle undergoes great dilatation and hypertrophy This is necessary for the maintenance of even a minimally adequate aortic output since a portion of each ventricular stroke volume is 'wasted'' by escape through the incompetent mitral valve into the dilated left atrium Obviously, this is less prominent with smaller leaks, and is insignificant in minimal ones even though a persistent systolic murmur may be heard If the total left ventricular output falls off for any reason a larger proportion is lost through the incompetent mitral valve and the aortic output is disproportionately reduced Hence depression from surgery or blood loss is very poorly tolerated in these cases (Fig 1, *A* and *B*)

The severity of the clinical course in mitral insufficiency (and severity of prognosis for duration of life) is directly proportional to the size of the leak Undoubtedly, it is inversely proportional to the vigor and tone of the left ventricular myocardium Presumably, as will be indicated later on, the type of the lesion causing the incompetence is also of primary importance since a coexisting stenotic element may tend gradually to reduce the magnitude of the leak while insufficiency due to annular dilatation tends progressively to become worse

Mitral regurgitation may be classified either physiologically according to the size of the leak, or pathologically according to the type and extent of the anatomical abnormalities which exist.

PHYSIOLOGIC CLASSIFICATION

Physiologically the insufficiency may be divided simply into plus 1, 2, 3, or 4 grades of severity according to the magnitude of the leak per beat. This may be reflected by the clinical features of disability, increase in the cardiac size, "paradoxical" pulsations of the left atrium upon fluoroscopy, and a specific pattern on the "wedge" tracing (capillary pressure curve) obtained by cardiac catheterization. There is great difficulty, however, in drawing sound conclusions even from this last type of investigation. The frequency of atrial fibrillation (present in 71.3 per cent of those of our patients who were definitively operated upon for this lesion) seriously limits the conclusions which can be drawn from such pressure curves.



Gross Left Ventricular Output
100 c c / beat

A

Gross Left Ventricular Output
75 c c / beat

B

Fig 1.—*A* In severe mitral insufficiency a significant portion of the left ventricular output is wasted by reflux into the low pressure left atrium. *B* If the left ventricular tone becomes diminished its total output falls off but a larger proportion of this goes back into the left atrium causing a much greater reduction in the effective aortic output.

Ultimately no doubt physiologists will develop a method for accurate measurement of the volume of blood lost from the left ventricle per heartbeat. Until that time there is no better guide to the magnitude of the insufficiency than digital estimation by intra-atrial examination of the size of the regurgitant jet. It is realized of course that this varies with the level of the systolic blood pressure and the vigor of the ventricular contractions and that the velocity and cross sectional area of the column or "bolus" of regurgitated blood may produce a varying tactile sensation. However, with experience and the application of common sense a surgeon can come to a reasonably reliable conclusion as to the magnitude of the insufficiency in any given case. Certainly he will be able to detect any significant alterations in the regurgitation which may occur as a result of surgical manipulations.

In order to obtain some reasonable consistency in estimates by various operators, we have attempted to achieve a rough quantitation of the magnitude of the leak. The tactile sensation associated with palpation of a regurgitant jet of blood may be experienced vicariously by ejecting measured amounts of water from a syringe against the tip of a finger immersed in a basin of water. By using syringes with different sizes of opening an appreciation of the differences in tactile perception of a large or small caliber jet may be attained. It is realized that there are gross elements of inaccuracy in this evaluation, and that only a considerable experience will render a surgeon reliable in his estimates. At the present time, however, there is no better method of evaluating the size of the valvular leak.

We consider as 1-plus an insufficiency in which there is a very small regurgitant jet, varying from the very least perceptible to a slightly more prominent one. Probably such leaks amount to no more than 5 c.c. per heartbeat.

Two plus regurgitations are somewhat larger, perhaps amounting to 10 c.c. leaks per heartbeat.

Three plus regurgitations are appreciably larger, probably ranging from 10 to 30 c.c. per beat.

A 4-plus insufficiency is a very large one. It may well amount to over 100 c.c. of regurgitation with each cardiac systole.

In Table I, we have classified 349 cases of mitral regurgitation in which a digital estimation of the leak was recorded.

TABLE I. PHYSIOLOGIC CLASSIFICATION IN 349 PATIENTS WITH MITRAL INSUFFICIENCY, IN AUTHOR'S SERIES

GRADE	NUMBER	PER CENT
I (1 to 5 c.c.)	99	28.3
II (5 to 10 c.c.)	77	22.1
III (10 to 30 c.c.)	137	39.3
IV (30 c.c. and above)	36	10.3
Total	349	100

CLASSIFICATION ACCORDING TO PATHOLOGY

Briefly stated, mitral insufficiency may be of congenital, traumatic, functional, or organic origin (Table II).

TABLE II

CLASSIFICATION OF TYPES OF VALVE IN MITRAL INSUFFICIENCY (PATHOLOGIC)	NUMBER OF CASES	PERCENTAGE
Functional insufficiency	58	13.7
Organic or mechanical insufficiency	158	37.3
Traumatic insufficiency		
Insufficiency created	153	36.1
Insufficiency increased	47	11.0
Congenital insufficiency (Isolated valvular lesion)	8	1.9
Total	424	100.0

Congenital Mitral Insufficiency.—While, no doubt, there may be many different congenital malformations of the mitral valve which can produce insufficiency, we have encountered only two types. Three patients have had one or more perforations of one or both valve leaflets. In five instances mitral insufficiency was recognized during digital examination of the mitral valve in patients with atrial septal defects of the persistent ostium primum type. In two instances it was proved subsequently to be due to a congenital cleft in the septal leaflet of the mitral valve (Fig 2, *A*, *B*, and *C*).

Traumatic Insufficiency.—Occasionally, mitral regurgitation may be produced by a stab or gunshot wound of the thorax. Adam[6] has reported an instance of traumatic mitral insufficiency due to bullet injury of the valve leaflets. However, this must be an extremely rare occurrence clinically since patients rarely survive such cardiac injury.

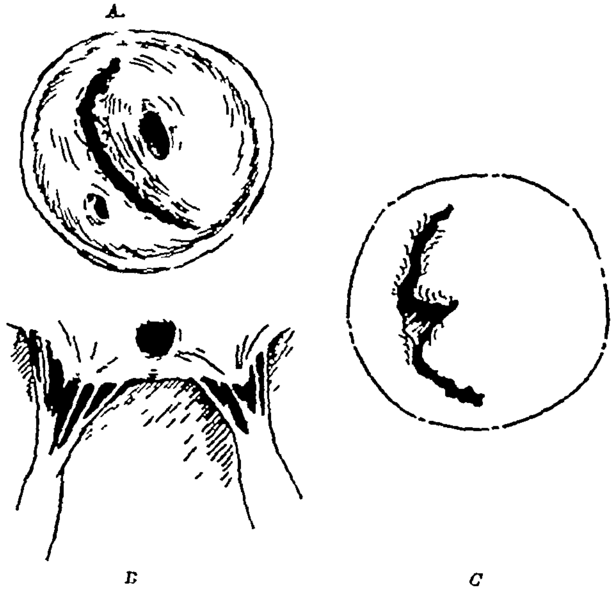


Fig 2.—*A* Congenital mitral insufficiency due to perforation of a leaflet. *B* Note accurate coaptation of valve lips. *C* Congenital mitral insufficiency due to primitive cleft in septal leaflet. (From Bailey, Surgery of the Heart, courtesy Lea & Febiger.)

A much more common type of traumatic injury now that surgery for mitral stenosis has become a frequent undertaking is the inadvertent creation of regurgitation during attempts at surgical mobilization of the fused valve cusps. This has been observed in 24.8 per cent of a series of 635 consecutive patients with pure mitral stenosis and 26.7 per cent of 176 cases with mitral stenosis associated with insignificant (1-plus) regurgitation. It was of no clinical consequence in the vast majority of the cases, merely representing a recommended extension of the commissural separation as far as technically feasible up to the point of the first detectable beginning of regurgitation. In a few instances, however, the produced regurgitation was serious as indicated by an operative mortality of 8.8 per cent in these cases in contrast to a 7.9 per cent mortality in those in whom no insufficiency was produced.

This kind of traumatic insufficiency varies considerably in type as well as in magnitude. Probably the least serious type is that in which the commissural separation is extended somewhat beyond the normal orificial limits and hence beyond the limits of tendinous support, so that the unsupported partially flexible extremities of the newly created valve "lips" tend to turn backward during ventricular systole.

A somewhat more serious type of traumatic insufficiency is one in which the line of created valvular separation deviates slightly from the true commissural line. This results in a reduction in the support of one leaflet and in a partial turning back of a portion of one valve edge.

An extension of the commissural separation fully into the heart wall may result in division of the atrioventricular annulus fibrosus. This permits a separation of the divided ends of the annulus and hence of the valve edges at this extremity of the orifice which completely prevents approximation during systole.

Still more severe is the regurgitation which results from separation of one leaflet from all of its tendinous supports at one extremity of the valve. This is due to a gross deviation of the line of separation from the natural anatomical commissure, resulting in a "flail" action of the detached end of the leaflet.

Maximal regurgitation is produced by an actual division of the continuity of one of the valve leaflets. This, of course, is greatest when the septal leaflet is divided completely, death usually taking place within fifteen minutes of the injury. While some have pointed out that comparable injury of the mural leaflet is less serious clinically, nevertheless, it is a surgical disaster which at best is attended by great left ventricular enlargement and reduction in cardiac reserve.

There are certain unusual or bizarre types of trauma which may cause regurgitation, such as inadvertent perforation of a cusp with a valvulotome, or rupture of a papillary muscle. They are particularly difficult to correct surgically (Fig. 3, *A-H*).

"*Functional Insufficiency.*"—In a loose way, it is generally recognized that a lack of tone of the myocardium may result in a dilatation or overstretch of the mitral annulus fibrosus. Hence, even a valve with normal leaflet structure becomes unable to hold back the regurgitant stream because of the large size of the atrioventricular canal. Most clinicians think of such regurgitation as essentially transient and reversible, and hence of little serious significance.

No doubt, such reversible annular dilatation may occur during toxic states, *in the course of acute infections,* and in certain types of congestive heart failure due to loss of myocardial tonicity and hence of the myocardial sphincteric action which normally is exerted about the annulus fibrosus with each ventricular systole.[7] Such *insufficiency apparently is transient,* disappearing with recovery from the initiating toxemia or congestive failure.

However, there are other forms of annular dilatation which may cause a less reversible "functional insufficiency." These are conditions associated with great left ventricular enlargement. Essential hypertension and aortic valvular disease either stenotic or regurgitant, not infrequently may be associated with mitral insufficiency of this type. *Presumably an improvement in the predis* posing condition might lead to a reduction in the size of the left ventricle, and hence in the size of the annulus, and thus might cause restoration of full mitral competence

Apparently the rheumatic process may cause a weakening of the fibrous elements of the mitral valve ring (annulus fibrosus) so that a more persistent or permanent type of annular dilatation results At autopsy or operation, the left ventricle and atrium are seen to be huge with little or no constriction between them During life, a gross systolic thrill may be palpated over the surface of the dilated and hypertensive left atrium and there may be a visible systolic dilatation or 'pulsation' of the latter Digital intra atrial examination during life will reveal functioning flexible valve cusps which appear to be en-

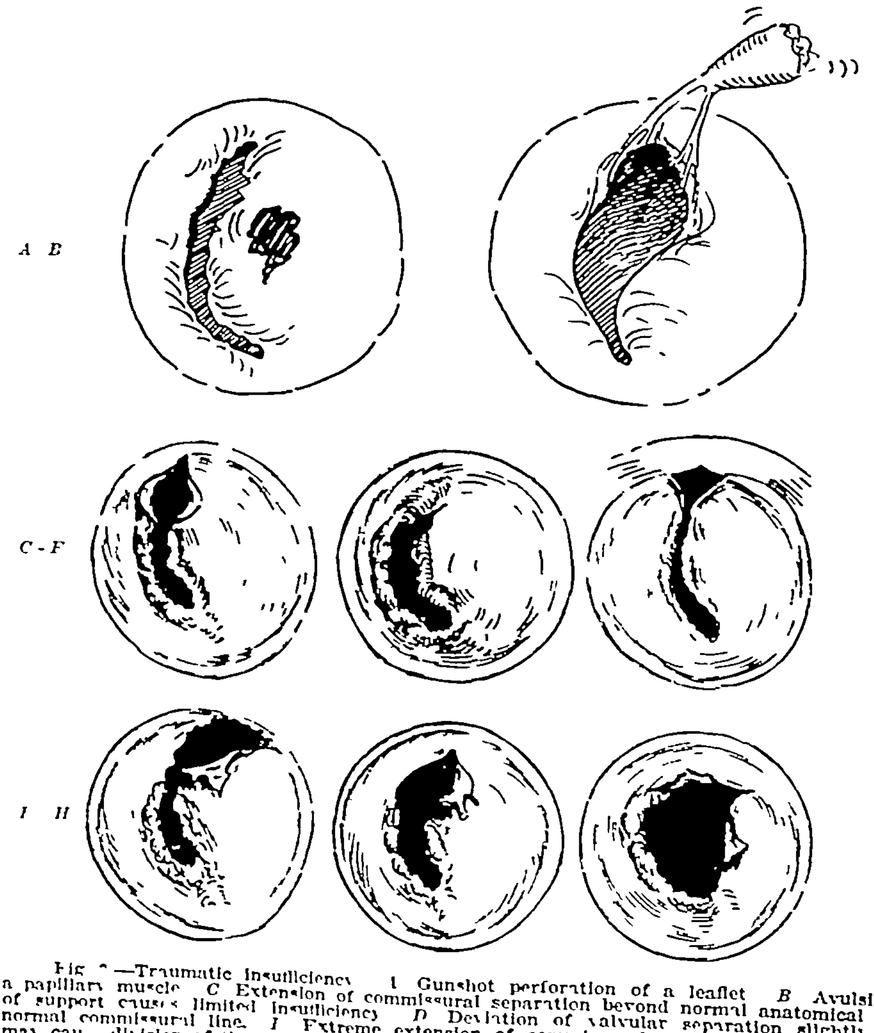


Fig [illegible] —Traumatic insufficiency A Gunshot perforation of a leaflet B Avulsion of a papillary muscle C Extension of commissural separation beyond normal anatomical limits of support causes limited insufficiency D Deviation of valvular separation slightly from normal commissural line E Extreme extension of commissural separation into heart wall may cause division of the atrioventricular annulus fibrosus F Separation of one leaflet from its heart wall attachment G Flail valve due to separation of a leaflet from its supporting chordae at one extremity of the orifice H Division of the continuity of a leaflet causes great insufficiency tirely normal in structure, a valve orifice of normal size or larger than normal, and a large regurgitant jet of blood which emerges with each ventricular systole from the posterior portion of the valve orifice only. The anterior portion of *the valve orifice remains completely competent. In mild cases the regurgitation* will be limited to that portion of the orifice which is immediately adjacent to the posterior commissure, but in the more severe cases it may involve up to or even more than half the length of the valve orifice beginning at its posterior extremity (Fig. 4, *A*, *B*, and *C*).

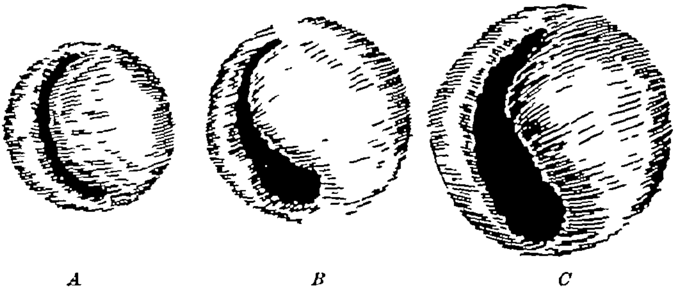


Fig. 4.—Functional insufficiency due to annular overstretch. The leak is always posteriorly located. *A*, Normal valve orifice. *B*, Moderate functional insufficiency. *C*, Extreme functional insufficiency.

Progressive Annular Dilatation Due to a Vicious Mechanism.—While undoubtedly there are other pertinent factors, including the condition of the myocardium, especially with respect to rheumatic activity, it appears that once annular dilatation has progressed to or beyond a certain critical point, a vicious mechanism becomes established. Since the only natural mechanisms compensatory for mitral regurgitation are ventricular dilatation and hypertrophy, at least the former phenomenon will take place as soon as insufficiency appears. However, the size of the atrioventricular canal is primarily a function of the size of the left ventricle (unless fibrous contraction of the annulus has been caused by the rheumatic process). Hence the ventricular enlargement tends to cause further dilatation of the mitral annulus. This produces more valvular insufficiency which, in turn, requires further compensatory ventricular dilatation. This leads again to further annular overstretch, and so on.

Hence these individuals exhibit progressive and marked cardiac enlargement and continuous decline in myocardial reserve. Some have contended that this phenomenon, especially when it occurs in young persons following a bout of rheumatic fever, is primarily an expression of cardiac deterioration due to an active rheumatic myocarditis. However, the authors feel that the overwhelming mechanical burdens associated with this vicious mechanism if imposed upon even a normal myocardium must lead to its progressive exhaustion and failure. Must not such a process then be even much more deleterious to the diseased heart? Following such reasoning to its logical conclusion and especially in consideration of the overwhelming mortality associated with the conservative treatment of these cases, one might consider the known coexistence of rheumatic activity to be an urgent indication for corrective surgery if such could be performed with a reasonably low risk rather than a contraindication as is generally believed by most clinicians. Naturally, common sense must be exercised in excluding the desperately ill patients whose myocardium would not tolerate even a temporary additional strain and in applying the appropriate preoperative preparatory measures to reduce the operative risk and to enhance the chances for subsequent clinical benefit.

While naturally it might be expected that symmetrical dilatation of the mitral annulus would lead to incompetence greatest in the central portion of the valve orifice similar to the central gap caused by symmetrically stretching a sheet of rubber with a curved incision in its substance, this is seen only when one of the leaflets is found at a higher level than the other in the atrioventricular canal. Here the valve orifice is arcuate with a central leak. Presumably this lesion is caused by unequal suspension of the two valve leaflets, probably due to unequal shortening of their tendinous supports. In these patients pressure with an intracardiac finger tip against the higher leaflet usually will restore full competence and abolish the regurgitant jet.

In most cases the anterior portion of the valve orifice remains fully competent while the portion near the posterior commissure becomes gaping and leaks. Probably the explanation for this phenomenon lies in the relatively greater amount or extra reserve of valvular tissue which exists in the anterior portion of the valve cone than is found posteriorly. Anatomical studies by the authors upon normal freshly obtained human hearts reveal a constant differential between the amount of apicobasal systolic leaflet overlap (zone of contact) in the anterior portion of the valve and that observed posteriorly. Frequently there is little or no leaflet overlap during systole in the region close to the posterior commissure. Progressive symmetrical dilatation of the annulus will result in increasing separation of the bases of the leaflets, gradually "using up" the available "reserve" valvular tissue and reducing the systolic overlap of their free margins. Obviously, the relatively slight amount of excess valvular tissue which exists posteriorly soon will be exhausted as this process advances, leading to failure of systolic marginal approximation and incompetence, while at least edge contact of the leaflets is maintained anteriorly. A similar mechanism would seem to be responsible in many of the cases of posterior incompetence associated with symmetrical rheumatic retraction of the valve leaflets (Fig 5, *A-F*).

Fifty-eight of our patients were considered to have this type of insufficiency in pure form that is unassociated with any detectable degree of stenosis or organic distortion of the valve leaflets. It must be realized however that this type of incompetence may become engrafted upon any of the other types of regurgitation if enough flexibility of the valve structures persists to permit annular dilatation to influence the size of the valve orifice. This is particularly pertinent in cases of operatively produced traumatic insufficiency of significant magnitude where natural attempts at compensation may result in great enlargement of the left ventricle and consequently in the production of significant annular dilatation. In turn this increases the size of the leak thus setting into play the factors responsible for the vicious mechanism described. However, it may be interrupted by the limits of valve flexibility in these cases. Likewise, functional insufficiency due to annular dilatation may be a factor in the over all picture of mitral regurgitation in many patients with incompletely rigid valves who initially developed their leak because of rheumatic distortion of one or both leaflets. It is difficult to estimate what part such superimposed "functional insufficiency" may play in the physiologic handicap associated with organic valvular incompetence in any given case. Therefore, we have classified such mixed cases of mitral insufficiency under the organic lesions.

Mitral Insufficiency Due to Acquired Organic Rheumatic Distortion of the Valve Leaflets.—In this condition the mitral leaflets are thickened and retracted due to rheumatic deformity and the pathology tends to resemble that of mitral stenosis with which it practically always is associated. The magnitude of the regurgitation varies greatly, and may be considered, in many cases, to be inversely proportional (reciprocal) to the amount of coexisting mitral stenosis.

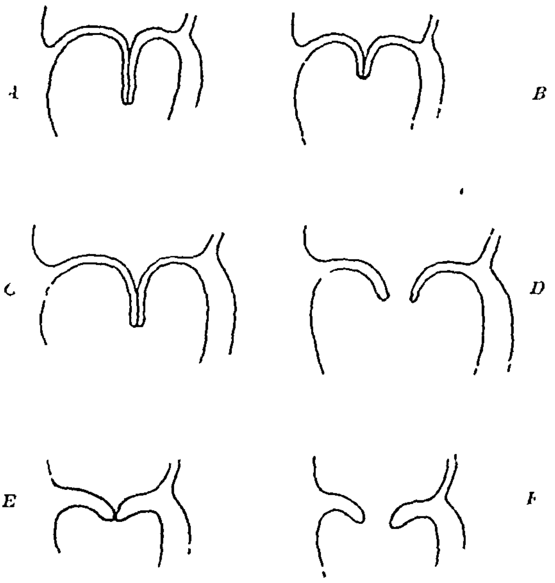


Fig. 5.—Anatomical explanation for posterior localization of incompetence due to annular dilatation and to rheumatic shortening and retraction of leaflet substance. *A*, Long section of normal valve near anterior commissure during ventricular systole. *B*, Same near posterior commissure. *C*, Edge approximation is maintained anteriorly in annular dilatation due to existence of reserve valvular tissue. *D*, Failure of edge approximation in posterior portion of valve in annular dilatation. *E*, Edge coaptation persists anteriorly even with shortened and thickened leaflets. *F*, Near the posterior commissure even slight leaflet retraction causes incompetence.

Indeed, one might presume that the presence of mitral stenosis is to some degree compensatory to mitral incompetence. While it is probably true that initial insufficiency (perhaps due to annular dilatation) may become reduced to a considerable extent by the subsequent development of a stenosing lesion, yet both mitral stenosis and insufficiency repeatedly have been observed by us to coexist in relatively serious form.

Here, as in cases of functional mitral insufficiency, the incompetence is nearly always localized to the posterior portion of the valve orifice. Frequently, the anterior portion of the valve orifice is obliterated by stenotic fusion of the leaflets involving the anterior peripheral and perhaps most of the central segment of the valve orifice. This results in a "teardrop" shaped orifice with its blunt rounded extremity adjacent to the posterior commissural tissue Frequently the substance of the mural leaflet appears to be locally retracted, forming an "incisura" (Fig 6, *A*, *B*, and *C*)

There may be two mechanisms by which such posterior incompetence and stenosis may develop In one, the valve initially may have been subject to annular dilatation and "functional insufficiency" perhaps during the toxic phase of the rheumatic activity The subsequent development of stenosis follows its usual pattern of centripetally progressing commissural obliteration by cross-fusion of the portions of the leaflets which come into apposition during ventricular systole However, the failure of leaflet apposition to take place posteriorly even during the height of ventricular systole, effectually prevents even the beginning of valvular adherence in this region Hence incompetence and incomplete valvular coaptation persist posteriorly while progressive cross-fusion of the leaflets advances from the opposite valve extremity until a small posteriorly located "teardrop shaped orifice is created This is both stenotic and incompetent although the former element usually predominates Obviously, one may encounter any intermediate stage in the course of this development (Fig 7 A and *B*)

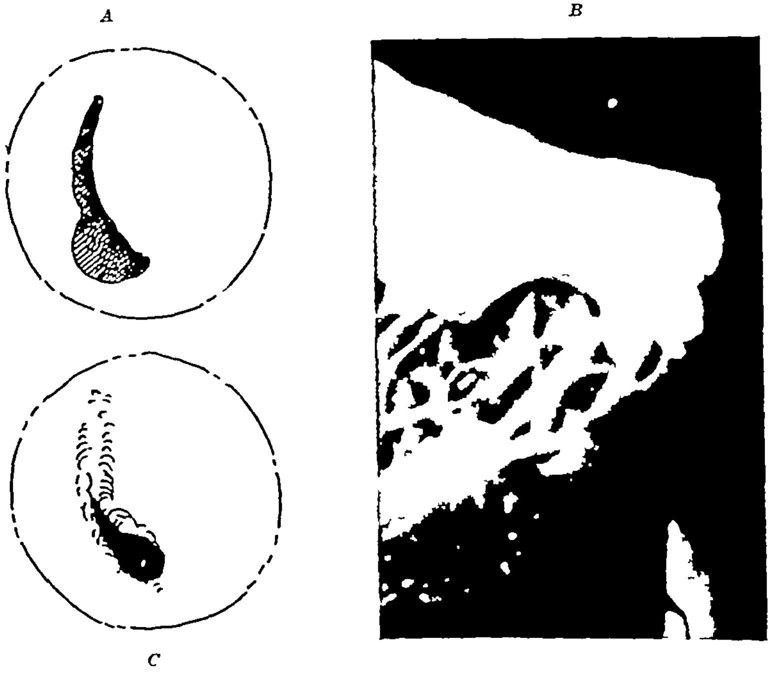


Fig 6—Typical incompetence due to rheumatic retraction of the leaflets and associated with a varying amount of stenosis *A* Slight associated stenosis Retraction of posterior portion of mural leaflet causes incompetence *B* Photograph of locally retracted mural leaflet showing posterior incisura. (Reproduced with permission of Dr Silvio Carvalhal Dept. of Pathology São Paulo Hospital São Paulo Brazil) *C* Predominant associated stenosis (teardrop valve)

Another explanation for the occurrence of such posterior incompetence relates again to the relative abundance of valvular tissue anteriorly in contrast to its paucity posteriorly Hence, symmetrical shrinkage or retraction of the valve edges will produce an exhaustion of the available reserve valvular tissue and failure of coaptation of the edges posteriorly before systolic apposition of the valve edges is prevented anteriorly Since a stenotic process usually develops simultaneously, again one observes the phenomenon of the stenotic and incompetent posteriorly located "teardrop" valve (Fig 5, *E* and *F*)

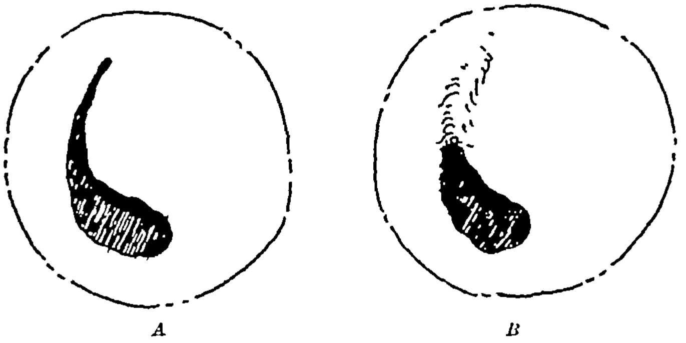


Fig 7 —Possible mechanism of development of teardrop valve *A* Functionally insufficient valve *B* Superimposition of stenosis upon the anterior (competent) portion of the valve Widely separated posterior portions of leaflets can never become directly fused together

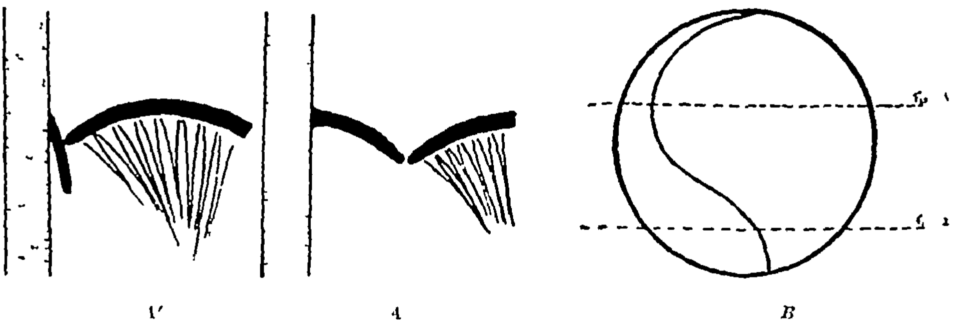


Fig 8 —*A* Section through anterior portion of valve *A* Section through posterior Paravisini interprets the normal mitral valve anatomy in this fashion The mural leaflet contributes little to competence near the anterior commissure but greatly posteriorly *B* Normal line of mitral valve closure Hence specific distortion and contraction of the mural leaflet must cause incompetence posteriorly but not anteriorly (Courtesy of Medicina Clinica.)

Paravisini and associates[8] have postulated that (1) the mural mitral leaflet contributes relatively little to valve closure in the anterior portion of the orifice while its importance is equal to that of the septal leaflet in accomplishing closure near the posterior commissure (2) the rheumatic process has a selectively destructive effect upon the mural leaflet Hence reasoning from these two premises it logically may be expected that the localization of mitral valve incompetence will usually be in the posterior portion of the orifice (Fig 8, *A* and *B*)

Actual measurements of the normal mitral valve leaflets in the fresh or preserved autopsy specimen indicate that the free margin of the septal leaflet characteristically is shorter than that of the mural (Fig 9, *A*) In five consecutive cases three of which were preserved specimens and two fresh specimens, the normal mitral valves were found to have the measurements indicated in

Table III Obviously since the free margins and the immediately subjacent zone of the leaflets must come into exact opposition during ventricular systole, this must be brought about largely by a reduction in the length of the longer mural leaflet by a "sphincteric" narrowing of the directly attached ventricular wall at the moment of systole This reduction in the length of the mural leaflet produces a transverse infolding or "wrinkling" of its substance, an appearance which some have interpreted as due to the existence of accessory or intermediate valve leaflets (Fig 9, *B*)

TABLE III ACTUAL MEASUREMENTS OF NORMAL MITRAL VALVES IN FIVE CONSECUTIVE CASES THREE PRESERVED SPECIMENS AND TWO FRESH SPECIMENS

	ANNULAR MURAL LEAFLET (MM)	FREE MURAL LEAFLET (MM)	ANNULAR SEPTAL LEAFLET (MM)	FREE SEPTAL LEAFLET (MM)
1	40	56	40	52
2	50	72	50	62
3	60	68	40	60
4	40	67	40	55
5	80	105	40	62

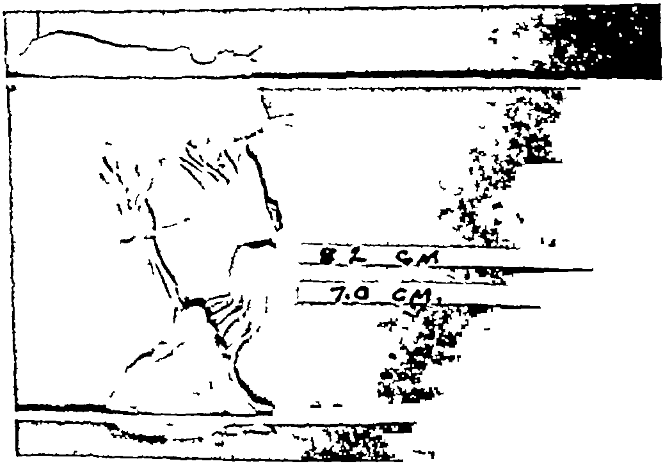


Fig 9 — A Representative specimen of normal human mitral valve Note that the free edge of the mural leaflet (upper) normally is longer than that of the septal *B* Normal human mitral valve in systole atrial view Note infolding or wrinkling in two areas of surface of mural leaflet Some might erroneously assume this infolding to represent the presence of additional or commissural leaflets actually they are due to the necessary infolding of its surface caused by the discrepancy in the lengths of the free margins of the two leaflets when the contraction of the left ventricle reduces the length of the mural leaflet to fit the free margin of the septal (Courtesy Prof Harald Okkels Institute of Human Anatomy Copenhagen Denmark) *C* Photograph of a human mitral valve showing true accessory or commissural leaflets This variant is believed to occur in 5 per cent of human cases (Courtesy Dr Silvio Carvalhal Dept of Pathology São Paulo Hospital São Paulo Brazil *D* Photograph of bull heart showing quadricuspid structure which is normal in this species *D₁* Atrial aspect *D₂* Ventricular aspect

Actually such accessory leaflets are rather rare in human beings Rusted, Scheifley and Edwards[9] have estimated that they may occur in perhaps 5 per cent of patients Fig 9 *C* illustrates not only the existence of an accessory leaflet in a human mitral valve but also a rheumatic "incisura" of the mural leaflet which has the effect of lengthening the free margin and thus causing insufficiency in part due to leaflet marginal disproportion

The bull heart characteristically presents two large accessory commissural leaflets in addition to the two major ones (Fig. 9, D_1 and D_2).

Naturally, there are many variations in the kind and magnitude of mitral regurgitation observed when it is due to thickening and distortion of the leaflets. In some the valve will have become converted essentially into a fibrotic or

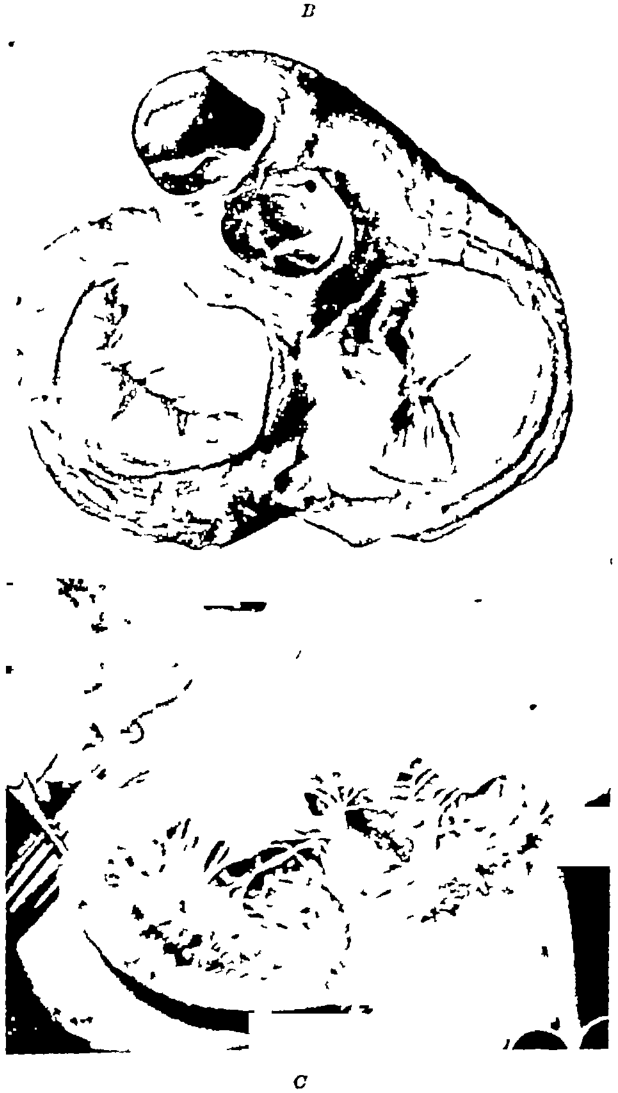


Fig. 9, B and C. (For legend see page 563.)

calcific plaque with a round or ovoid central opening. While such an opening ordinarily is small and stenotic, occasionally one is seen which is large enough to admit a man's thumb. Since such severe regurgitation cannot long be tolerated even by the strongest heart with the healthiest myocardium, these individuals have a relatively short life expectancy In an occasional patient the valve structures may become adherent directly to the adjacent ventricular wall, producing insufficiency (Fig 10 A, B, and C)

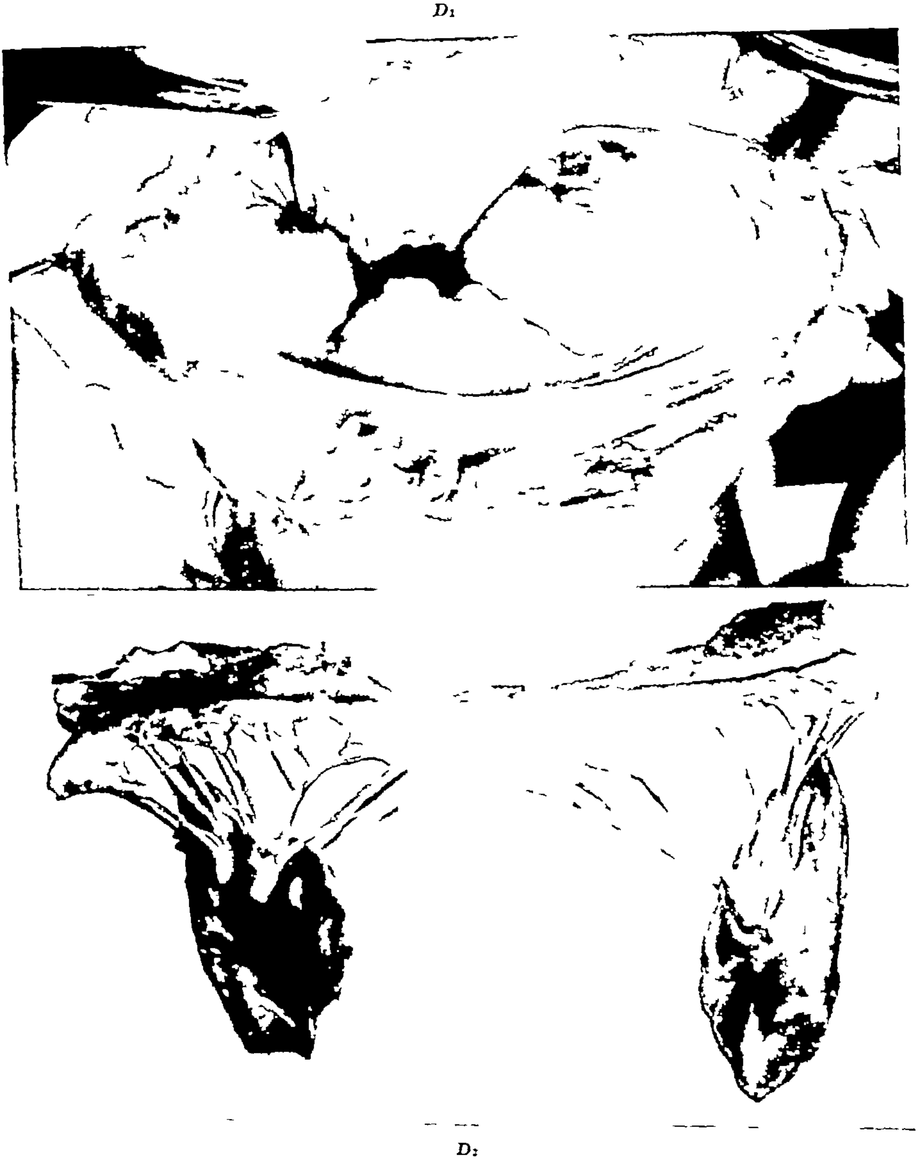


Fig 9 D1 and D2 (For legend see page 563)

There are many patients who present features of both functional and organic insufficiency in varying proportions These individuals may have relatively little associated over all reduction in the size of the valve orifice (little associated stenosis) but the thickening and distortion of the leaflets are typical of rheumatic disease

Another form of insufficiency which must be included in this classification is that which is associated with irregularity of the thickened valve edges which renders accurate apposition impossible. Such incompetence usually is found in association with a stenotic hard valve, often with extensive calcification of the leaflets. This type of incompetence nearly always is of relatively small magnitude and hence usually may be ignored clinically. It frequently becomes improved by readjustment of the valve coaptation after the performance of an effective commissurotomy (Fig. 11 *A* and *B*).

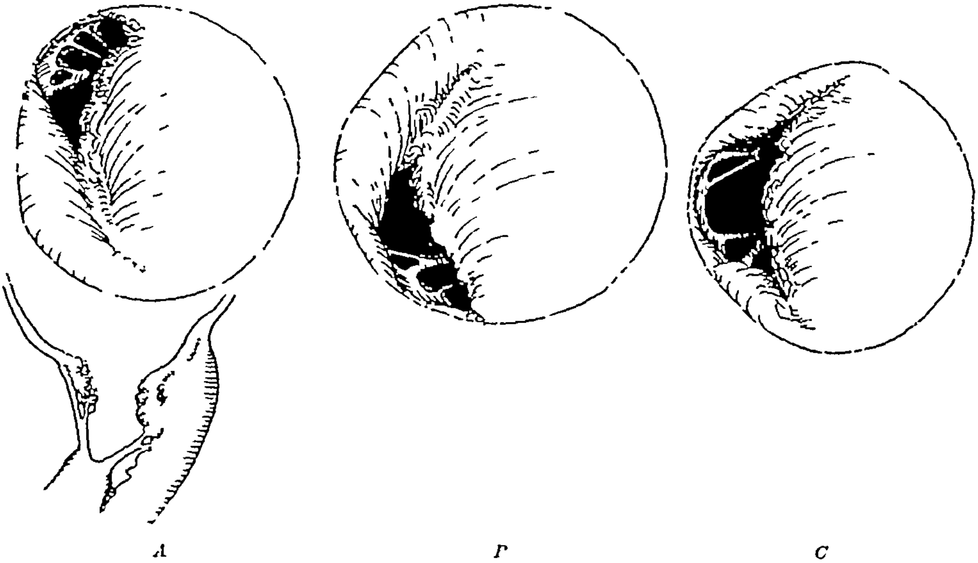


Fig. 10.—Mitral insufficiency due to direct adherence of papillary system and/or actual valve substance to the ventricular wall. *A*, Adherence of valve structures to ventricular wall in the region of the anterior commissure and *B* in the region of the posterior commissure. *C*, Adherence of the central portion of the mural leaflet or its supporting structures to the lateral ventricular wall.

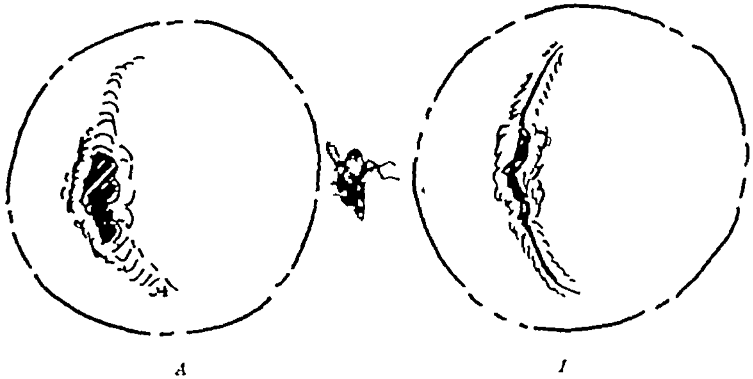


Fig. 11.—Insufficiency associated with stenosis in which the irregular hard margins of the often calcified valve may become more accurately apposed after performance of a proper commissurotomy. *A*, Predominantly stenotic but also incompetent valve. *B*, Improvement in competence after commissurotomy.

It will be observed that all forms of mitral insufficiency except that due to unequal papillary suspension and those with direct fusion of the leaflet to the ventricular wall present one feature in common—a relative or actual lack of valve substance Hence it would seem that any corrective measures effective for them must be designed to supply this lack of available substance

The treatment of valvular incompetence due to differential shortening of the chordae suspending the respective leaflets would seem logically to be such as would lengthen the shorter chordae or shorten the longer ones The former concept has been expressed both by Dodrill[10] and by Kay[11] They have attempted to detach acquired adherence between the papillary system and the ventricular wall by transvalvular digital separation

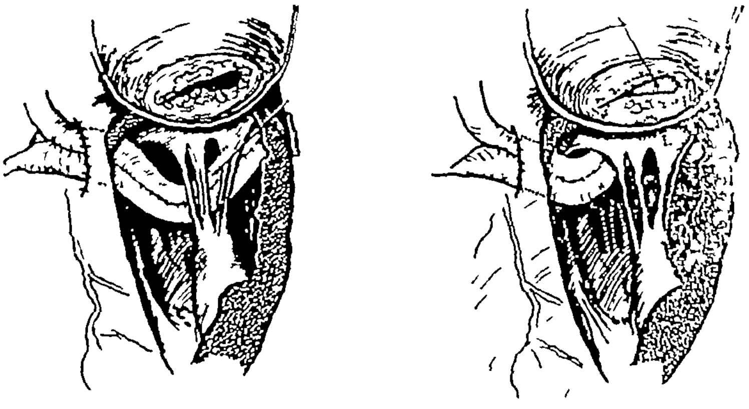
We* have attempted to advance the attachment of the leaflet which is displaced farther toward the atrium during ventricular systole by using one or more transventricularly placed pericardial sutures to draw the free edge of the leaflet somewhat farther toward the ventricular apex. This has worked reasonably well in this type of case Recently one of us (W L J) has modified this technique so that the leaflet is not suspended by a suture about the free edge (which must create some irregularity upon the line of leaflet coaptation and hence must create some new incompetence of a different type) The improved technique entails perforation of the higher leaflet by transventricular passage of a threaded probe The left index finger placed within the left atrial chamber guides the tip of the probe which subsequently follows the course of the finger to emerge from the opening in the tip of the left auricular appendage The suture it bears is grasped and the probe is removed from the heart A knot is tied in one end of a strip of pericardium 2 5 cm wide and the other end is cut in tapering fashion The pointed end is attached to the extremity of the transcardiac suture which emerges from the auricular appendage Traction upon the extremity emerging from the ventricular wall causes the pointed end of the pericardial strip to enter the heart to traverse the perforation in the valve and to emerge from the puncture in the ventricular wall The "knot" enters the left atrium and being too large to penetrate the perforation in the valve cusp comes to lie upon its atrial aspect somewhat lateral to the free margin Variable traction may be made upon the emerging ventricular extremity of this artificial chorda tendinea until maximal improvement in the regurgitation is determined by the intracardiac finger The extremity of the pericardial ribbon is then secured at that tension or at an estimated safer tension to the ventricular epicardium by direct suturing (See Fig 34)

MEASURES DESIGNED TO OVERCOME AN ACTUAL OR RELATIVE LACK OF VALVULAR SUBSTANCE

Murray[12] originally suggested the transventricular placement of a loosely swinging tissue hammock composed of an inverted vein segment, strengthened by a centrally placed strip of fascia or a tendon Bailey and associates[1] modified this technique applying a pedicled tube prepared from pericardium loosely across the ventricular aspect of the incompetent mitral orifice It was reasoned that such tissues loosely placed on the ventricular aspect of the mitral valve would tend to swing into the orifice tamponading it during each ventricular systole During diastole it would fall away from the mitral aperture to permit ventricular filling (Fig 12 A and *B*)

Such "hammock" valves initially worked well mechanically. However, their placement resulted in a high operative mortality (38 per cent in 52 cases). This was, in part, related to the trauma to the already overburdened and dilated left ventricle which tends easily to go into a state of standstill or ventricular fibrillation. Part was due to an initial tendency toward swelling of the graft which, on a few occasions, due to its increased bulk, produced significant displacement of the ventricular contents. More serious was the not infrequent production of a poorly understood hemorrhagic syndrome in which all cut surfaces would ooze fatally, in spite of replacement therapy or reoperation.

These grafts become replaced partially by fibrous connective tissue and shrink to perhaps two-thirds of each former dimension. Hence, the newly created valvular action becomes abolished in time. For these various reasons the procedure of "transventricular pericardial tamponade" was finally abandoned as clinically unsatisfactory as well as operatively dangerous.



A *B*

Fig. 12.—Transventricular placement of pedicled pericardial hammock in the treatment of mitral insufficiency. *A*, Position of graft during diastole. *B*, Position during systole. Leak is completely tamponaded.

Reconsideration of the whole problem and its various related facets led inevitably to contemplation of the clinical experience of others as well as our own group that opening of only one obliterated commissure usually is sufficient to produce great clinical benefit in patients with mitral stenosis. In our entire series of patients with mitral stenosis, treated by commissurotomy alone, we have found that surgical valvular separation was limited to the anterior commissure alone in 64.9 per cent of the cases and to the posterior commissure alone in 1.9 per cent. This final opening would represent, therefore, only the transverse central channel of the original mitral orifice plus one of the peripheral (designated lateral by Brock[13]) sloping segments of the mitral orifice. The residual flexibility of the valve structures in these individuals is usually sufficient to permit a satisfactory eccentric type of valve function as well as an adequate passageway for blood flow. If such a valve aperture in which the posterior peripheral segment remains fused is adequate to restore the patient's clinical health following commissurotomy for mitral stenosis, should not an identical aperture be equally adequate to bring about the health of a patient who has undergone an operation for the surgical correction of mitral insufficiency?

An affirmative answer obviously being appropriate to this question, an effort was made to devise a means of restoring the valve aperture in cases of significant mitral regurgitation to one in which the full-sized transverse portion of the central channel, and one full-sized peripheral segment can be assured,

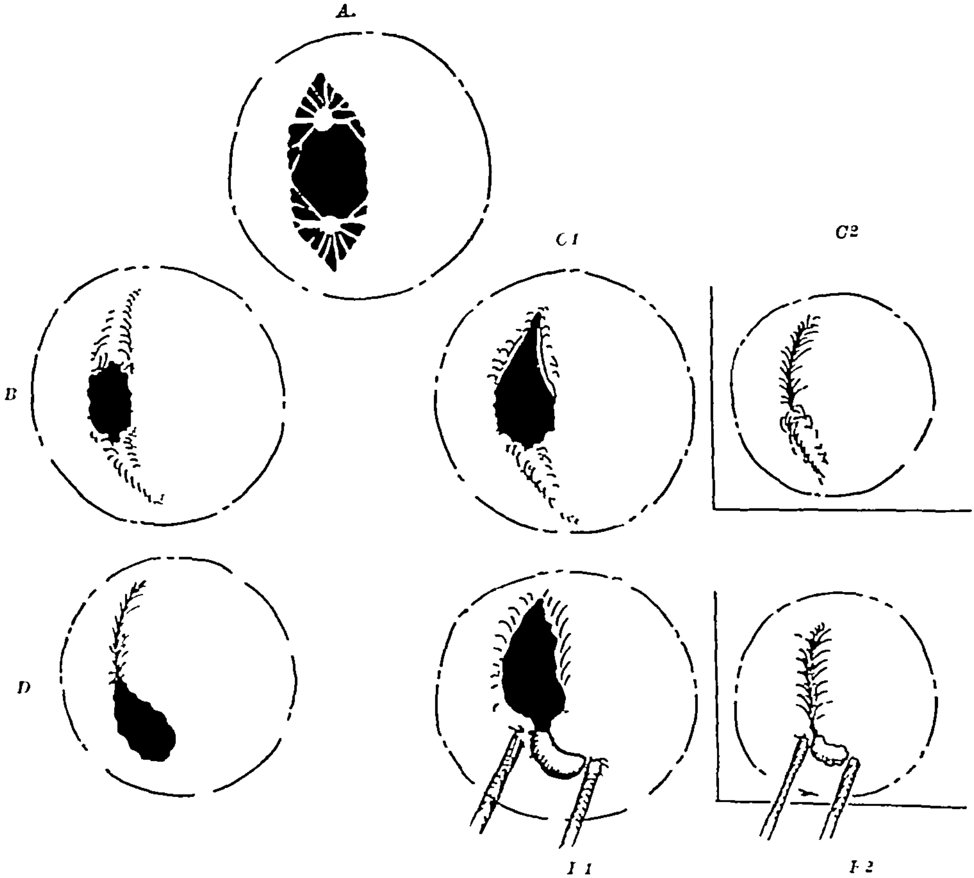


Fig. 13.—*A*, Anatomical division (Brock) of normal mitral valve orifice into three segments: a transverse central segment and two lateral or peripheral segments. Top view of valve. *B*, Mitral stenosis with obliteration of both peripheral segments. *C*, Anterior commissurotomy alone restoring orificial size to that of the central and one peripheral segment, establishes clinical health. *1*, ventricular diastole; *2*, ventricular systole. *D*, Mitral insufficiency limited to posterior peripheral segment. *E*, Suture obliteration of posterior peripheral segment with maintenance of central and one peripheral segment should provide adequate orificial size and function equal to that after commissurotomy. If anterior commissurotomy is necessary for associated stenosis, it should be performed before valvular suturing. *1*, ventricular diastole; *2*, ventricular systole.

while the opposite incompetent peripheral segment is obliterated by surgical suturing. Since the posterior peripheral segment is practically always the incompetent one, this is the one chosen for surgical obliteration. While the anterior peripheral segment often is adequately open as in insufficiency due to annular dilatation, all cases with coexistent mitral stenosis will require prior valve enlargement by anterior commissurotomy (Fig. 13, *A-E*).

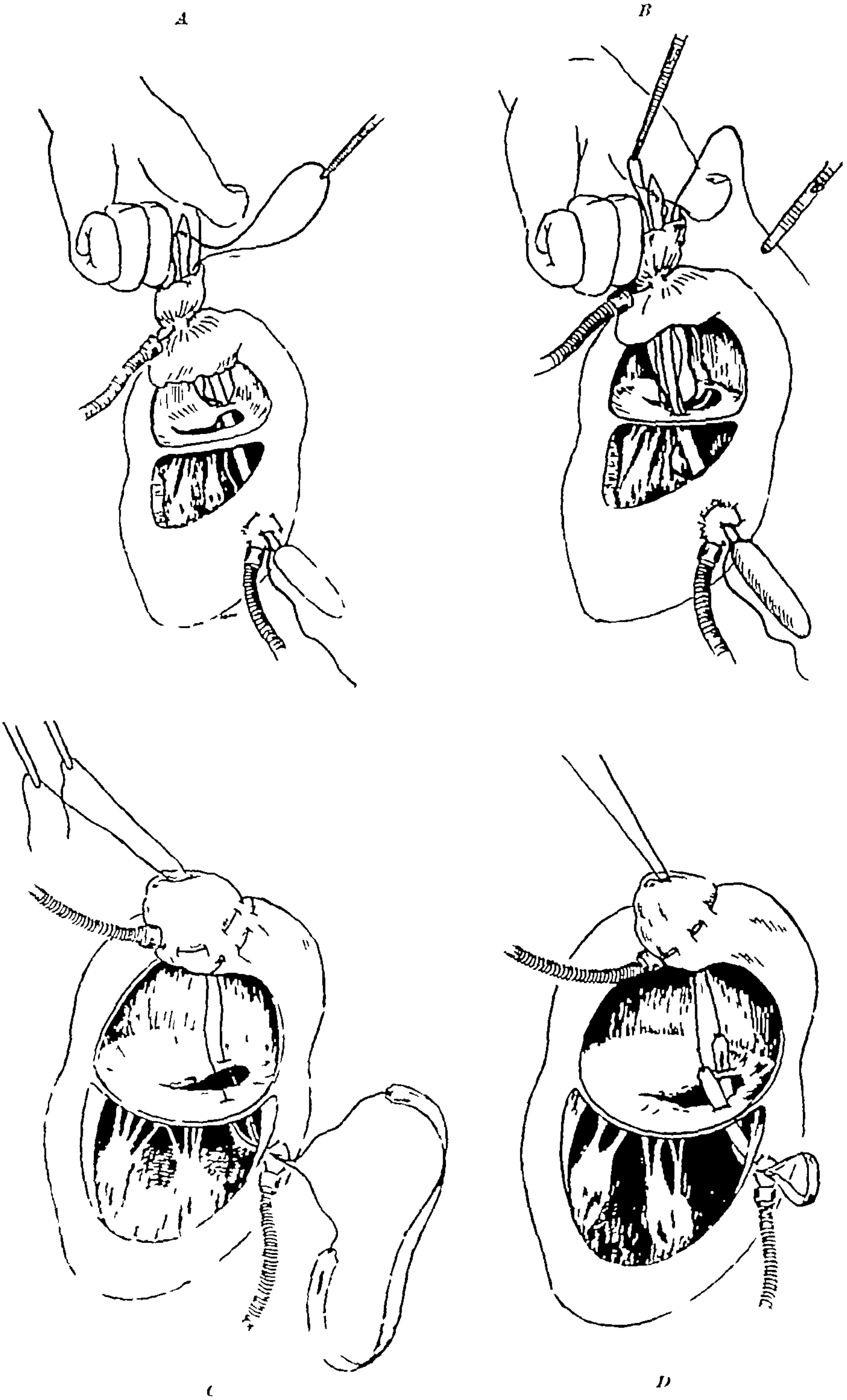


Fig. 14 A to D. (For legend see opposite page.)

The accomplishment of this objective, the surgical obliteration of the incompetent posterior peripheral segment of the valve orifice, while assuring adequately open and functional transverse and anterior peripheral segments, would be greatly facilitated by an open technique under direct vision Such a technique is not yet practicable but closed methods are already available which render this procedure fully feasible at this time

At first a simple method of suturing the valve was worked out in which a threaded probe was passed through the apex of the left ventricle and, guided by the intracardiac finger was caused to penetrate the appropriate valve leaflet at the selected point The probe tip then followed the intracardiac finger until it emerged from the opening in the left auricular appendage The suture material on one side of the probe was grasped and held while the probe was drawn back into the heart and disengaged from the valve Then it was redirected to penetrate the other valve leaflet at a selected site Again the probe tip followed the finger to emerge from the left auricular appendage Now the opposite side of the suture was grasped and held After withdrawing the probe from the heart the two leaflets were found to be separately penetrated by the two strands of silk suture an end of each emerging from the ventricular incision, the opposite emerging from the auricular

As previously described[2] initially it was considered satisfactory to attach the extremities of a living tissue strip to the ends of the suture material emerging either from the ventricular or the atrial incision and to draw them by traction upon the opposite ends of the suture material, into the heart, through the perforations in the valve and finally out of the opposite chamber of the heart By creating an 'eye in one extremity of the pericardial strip and passing the opposite one through it a ' noose was formed which could be tightened to any desired degree by simple traction upon the intact extremity The intracardiac finger was able to appreciate the effect this tightening of the noose had upon the regurgitant jet and hence upon the incompetence itself In some cases more than one such suture was used (Fig 14 *A-D*) This procedure has been designated by the term commissurorrhaphy

It would seem at first glance that such a procedure would fulfill all the requirements for the surgical correction of mitral insufficiency in the average clinical case The posterior incompetent peripheral segment of the orifice may be obliterated by approximation of the valve edges in this region This abolishes the regurgitation or at least diminishes it greatly On the other hand, maintenance of the full aperture of the anterior peripheral and the central transverse segment of the valve orifice would seem to ensure a suitable passageway for atrioventricular blood flow In individuals with significant coexistent mitral

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Fig 14 —Valvular suturing by transventricular passage of a threaded probe This technique proved [illegible] in application *A* Transventricular passage of threaded probe [illegible] valve [illegible] emerging from auricular appendage alongside operator's intracardiac finger One side of suture is grasped and held *B* Probe is partially withdrawn to [illegible] from ventricular aspect of valve By immediate redirection it pierces the [illegible] and again emerges from the appendage The opposite side of suture is grasped and the probe is withdrawn *C* After the probe is withdrawn two sutures completely traverse the chambers of the left side of the heart each penetrating a valve leaflet Either pair of ends may be attached to the extremities of a prepared pericardial ribbon *D* Re[illegible] the sutures with a strip of living tissue (pericardium) for atrial (or ventricular) [illegible] (Bailey et al Surg Clin North America W B Saunders Co)

stenosis specifically involving the anterior portion of the valve, this element of impaired valve function must be overcome by a preliminary commissurotomy procedure before applying the valve approximating sutures

DISCUSSION

Unfortunately, several untoward features were associated with this approach In a series of 72 patients operated on by this general technique or some close modification, there were 20 hospital deaths, a mortality of 27 8 per cent While this might be explained in part by the fact that this was a pioneering undertaking with a constantly changing developmental technique, and in part by the extremely poor condition of many of the patients chosen for this type of surgery, it became increasingly evident that the procedure was inherently too dangerous, and that it presented some other very practical drawbacks

One of the most obvious causes of mortality was the sudden onset of ventricular fibrillation which tended to occur especially during the manipulations of the left ventricle It seems to us that with the dynamically balanced circulation which these individuals exhibit, in which an appreciable and perhaps major portion of the left ventricular output traverses the incompetent mitral orifice to enter the relatively low-pressure left atrial chamber while the remainder is expelled into the high-pressure aortic lumen, a relatively slight depression in left ventricular vigor will result in a much greater proportional decline in aortic output since the majority of the reduced ventricular output will then tend preferentially to enter the low-pressure left atrium (Fig 1, *A* and *B*) Thus, even a slight fall in left ventricular output may precipitate a relative inadequacy of coronary filling and flow, and hence initiate ventricular fibrillation

It would seem that probe puncturing of the left ventricular wall, the repeated manipulation of the probe within the ventricle, the inevitable momentary distortion of the functioning valve, and the associated blood loss, all tend to produce ventricular fibrillation

Autopsy studies in several patients who died in the hospital showed that the pericardial suture or sutures had cut through the substance of the valve in several instances, presumably because of too great tension by the tough pericardial tissue in the presence of relatively fragile leaflets Of course, this occurrence was accompanied by a restoration or worsening of the pre-existing valvular incompetence (Fig 15) In another patient, the ventricularly suspended pericardial strip became broken (Fig 16)

Reflection suggested that the excessive pericardial strip tension was in part due to attachment of the free end to the ventricular epicardium since it was not observed when the pericardial strips were brought out of the relatively more yielding auricular appendage and were simply attached to its stump Moreover, it will be perceived readily that at the height of ventricular systole the mitral leaflets are forced backward, away from the site of ventricular suspension by any pericardial noose-suture combination thus increasing the tension

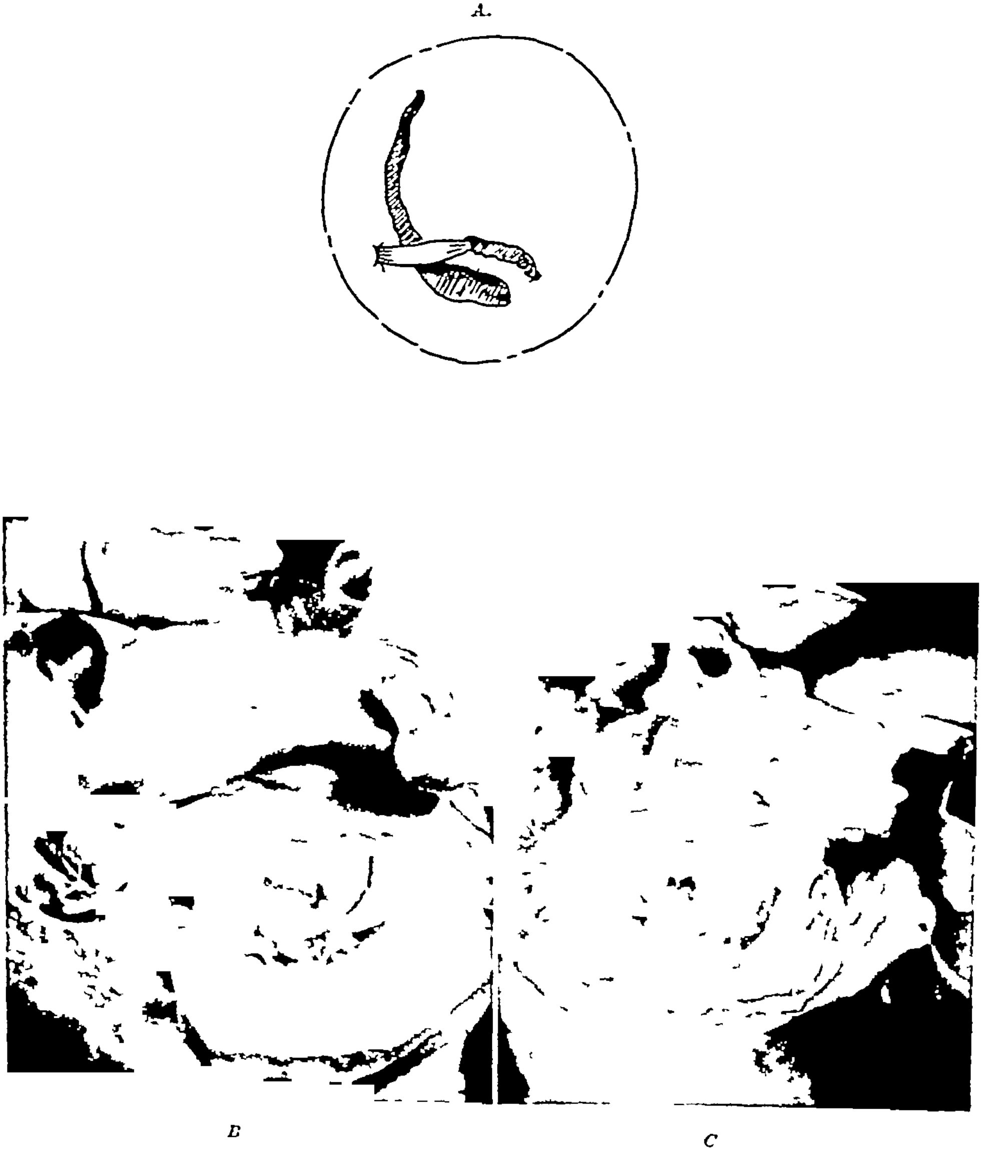


Fig 15 — An ugly possibility in noose-type suturing with ventricular suspension is tearing of the substance of the valve leaflets (if not heavily fibrosed) by repeated traction of the pericardial sutures during systole. *A* Diagrammatic representation *B* Actual photograph of valve three months after noose suturing and ventricular suspension *C* Expression of fluid from ventricle through lacerated valve substance in same case. (Courtesy Dr Silvio Carvalhal Dept. of Pathology São Paulo Hospital São Paulo Brazil)

upon the valve leaflets. If they have not become reinforced by a fairly marked degree of fibrosis, the incessantly repeated pull of the noose must certainly tend to tear through the valve substance.

On the other hand, suspension of the noose from the appendageal stump would seem to diminish this risk. Since the leaflets tend to approach the atrial chamber during ventricular systole, the "noose" tension would become diminished at this time. Also, it would seem that the relatively yielding attachment to the atrial stump would provide a cushioning effect against any very sudden increase in tension during systole. For these reasons, ventricular suspension, at least when a "noose" is used to approximate the valve edges, has been abandoned.

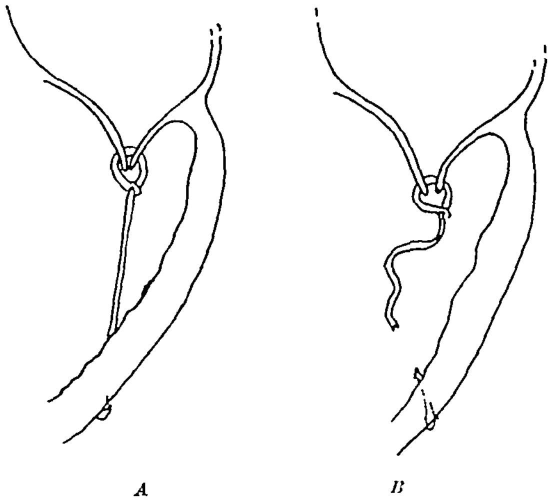


Fig. 16.—Disadvantage associated with suspension of sutured valve from the ventricular wall. Incessantly repeated strain from ventricular contraction may cause rupture of the pericardial strip. This is known to have occurred in one of the author's cases. *A*, Valve sutured. Ventricular suspension by noose technique. *B*, Dissolution of continuity of strip (six months after placement).

Of course, if noose tension were to become reduced at the moment when intraventricular tension is at its maximum, it is probable that regurgitation might not be as fully restrained as it would be were the tension fully maintained at that time. In view of our previous experience with the ultimate fate of transventricular pericardial hammocks, it was presumed that eventual shrinkage and fibrosis of the graft and the late extension of the fibrosing process into the adjacent valve leaflets would result in sealing of the posterior peripheral segment of the valve orifice by a "welding" or fusing of the adjacent valve leaflets together as well as to the tissue suture. That this does occur when the suture graft is large, is illustrated in Fig. 17, *A* and *B*. However, if the suture material is thin, its replacing fibrous tissue may become "stretched out" and functionless as shown in Fig. 18 *A*.

However, a most important factor which we have not yet considered is that in most instances of mitral regurgitation there is an actual or relative lack of *sufficient valvular tissue in the posterior portion of the orifice to permit edge* approximation of the leaflets except with the use of considerable tension upon the suture graft. Hence, unless these leaflets have become strengthened by fibrosis, they will not tolerate sufficient noose tension to restore full competence.

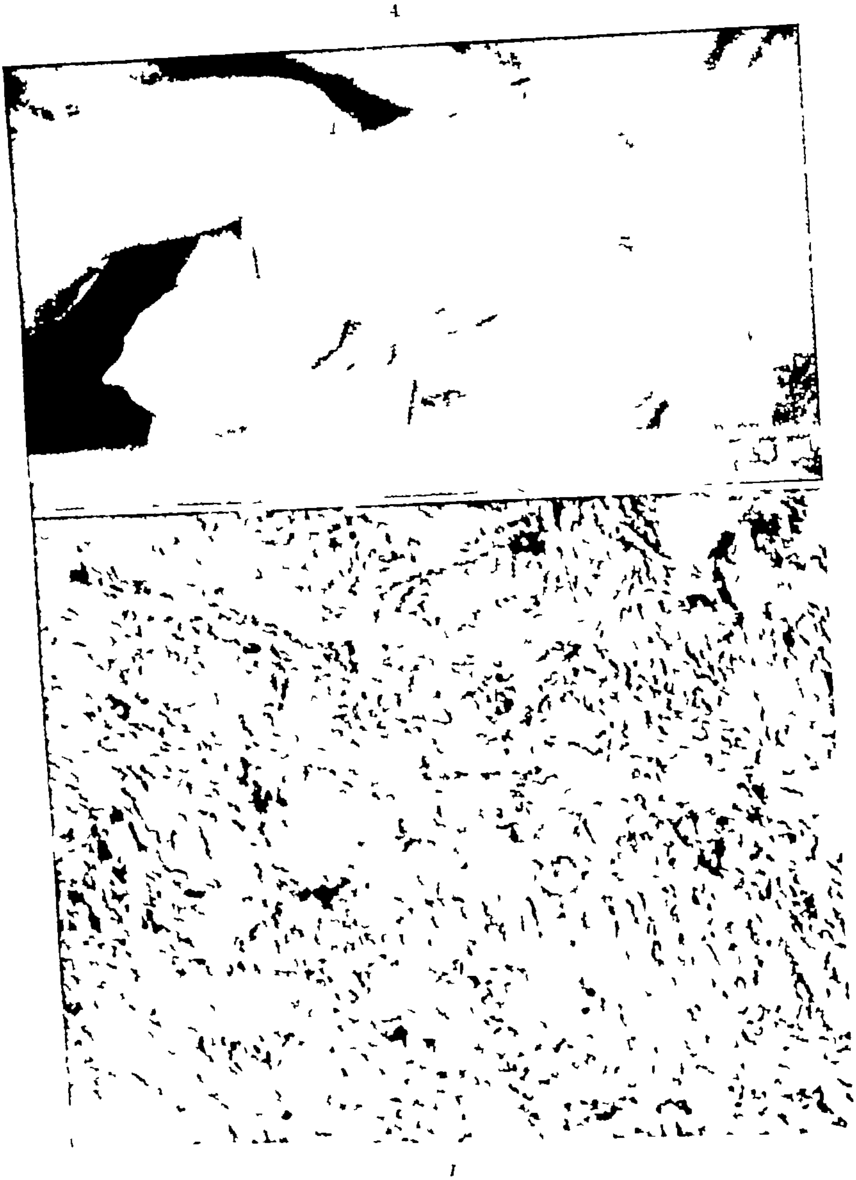


Fig. 1.—A, Gross appearance of mitral pericardial suture 1½ months after placement. Note welding together of graft and valve edges. Anterior two-thirds of valve orifice remain flexible and functional. B, Photomicrograph showing partial conversion of pericardium into fibrous connective tissue.

In other words, when there is a dearth of available valvular tissue, it seems necessary to supply it either by a grafting process or by the use of a prosthesis of some kind. The inherent disadvantages associated with the use of prostheses inserted within the circulatory system, and the specific and overwhelming dangers implied in their placement within or near the mitral orifice have deterred us from pursuing this line of thought.

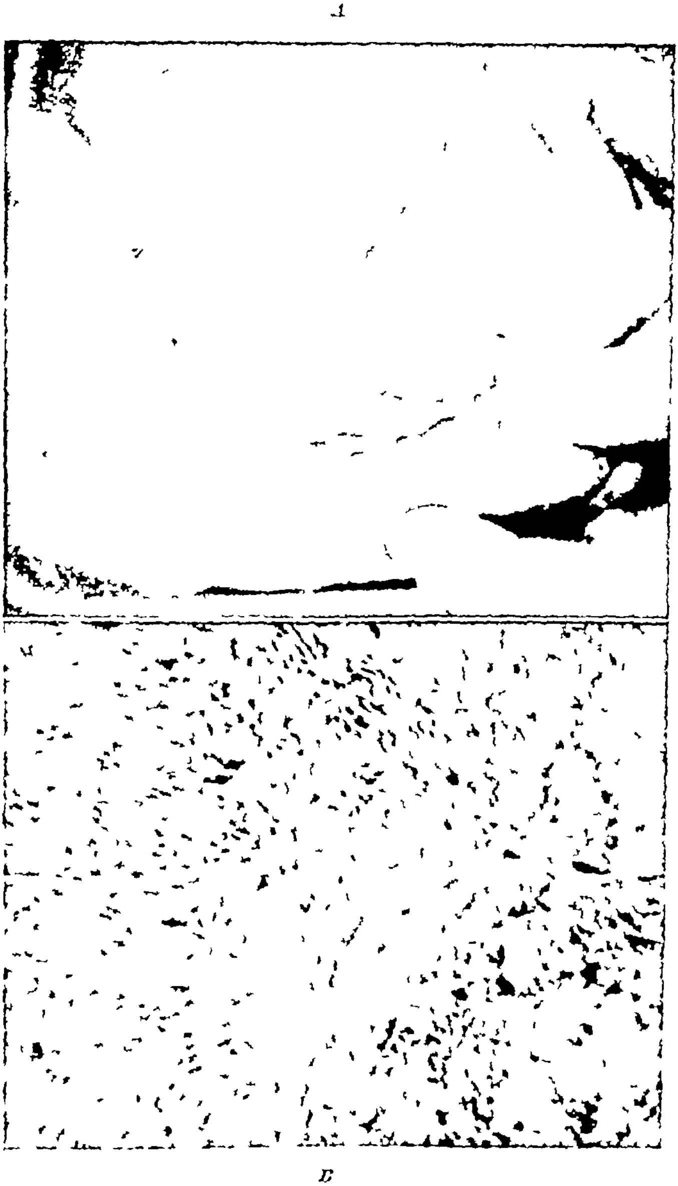


Fig. 18.—A, Very slender pericardial suture placed two years before death. Note stretching out. B, Photomicrograph of same transformed graft illustrating fibrous change.

Before considering the placement of tissue grafts within the cardiac chambers it would be well to establish the ultimate fate of pericardial tissue so placed.

Glover, Henderson, and associates[11] in 1953, after a series of experiments in which free and pedicled pericardial tissue was placed across the left ventricular chamber in dogs came to the conclusion that these grafts became degenerated and replaced by shrunken fibrotic cords (Fig. 19 *A-D*). Moore and Schumacher[15] in 1953 came to somewhat similar conclusions in a similar study (Fig. 20 *A* and *B*). Bailey, Lacey and associates[1] in 1952 had shown the early fate of such pericardial tissue and had pointed out the futility of using sheet pericardial material for the purpose of covering a septal defect (Fig. 21 *A* and *B*).

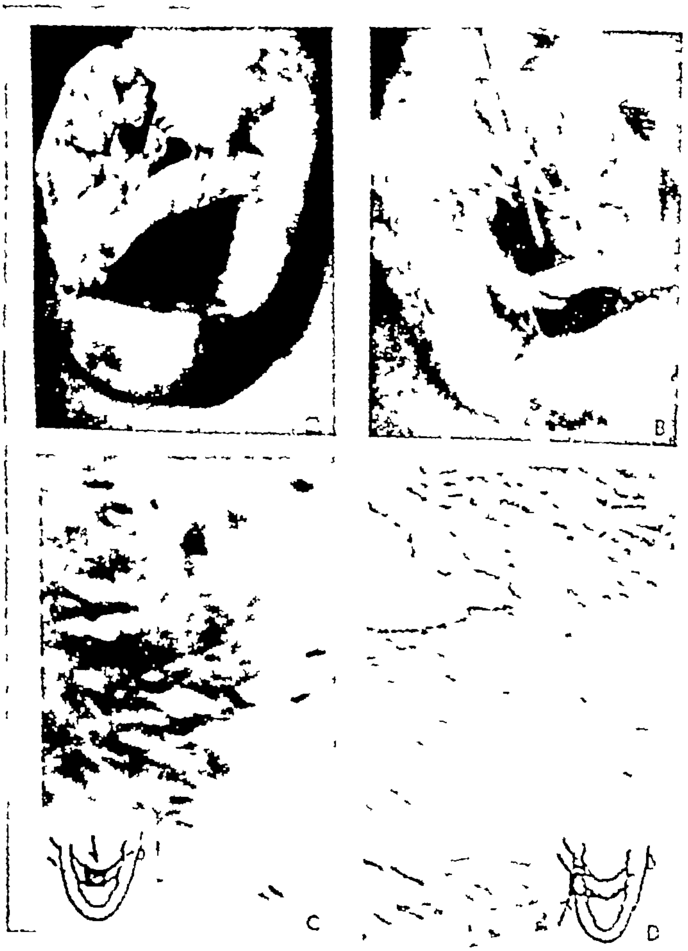


Fig. 19.—*A* and *B*, Experimentally placed pericardial grafts in dogs. *C* and *D*, Photomicrographs of sections of graft. (Glover, Henderson et al.: Surgical Forum 1952, Am. Coll. Surg. Reproduced with permission of W. B. Saunders Co.)

Today, with the availability of human patients with pericardial grafts and sutures placed as long as four years ago, we are in a position to clarify these doubts. Initially these grafts swell remarkably (Fig. 22). On four different occasions one of us (C. P. B.) has been able to examine digitally during life transventricular pericardial pedicled grafts placed 12 to 36 months earlier. In three instances, the graft had become shortened and stiffer, in two of them being stretched tightly across the left ventricular chamber but away from the valve. In one, the graft had become sealed to the valve orifice, completely

Fig. [illegible]0.—A, Photograph of pericardial graft placed in dog's heart fourteen weeks previously. B, Photomicrographs of sections through grafts 1½ weeks after placement. C, Photomicrographs of sections through grafts fourteen weeks after placement. (From Moore and Schumacher: Surgery 33: 173, 1953.)

restraining all regurgitation but producing a high degree of mitral stenosis. It was possible to perform an instrumental commissurotomy, cutting the graft away from the septal leaflet, thus producing good valve function as well as relieving the stenosis and without restoring the original incompetence The graft remained attached to the mural leaflet adding a considerable amount of new living tissue to its retracted free edge (Fig 23, *A* and *B*) From this experience came the concept of deliberately performing selective plastic grafting

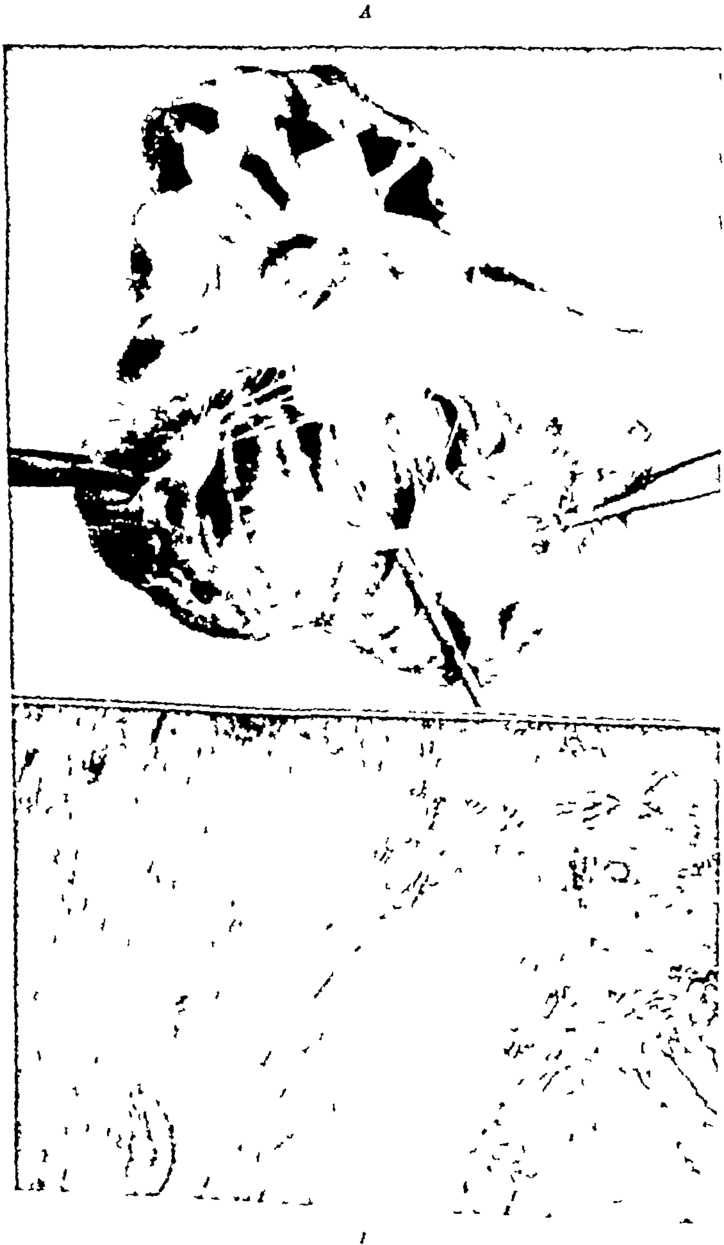


Fig. 23. *A*, Photograph and *B*, photomicrograph of shrunken [illegible] graft of pericardium the [illegible] months after [illegible] in [illegible] (From Bailey, [illegible] et al.: Ann. Surg. 136: 919, [illegible])

to the edge of the mural leaflet In the fourth case, the graft was somewhat smaller in caliber but appeared to maintain all of its original flexibility and length

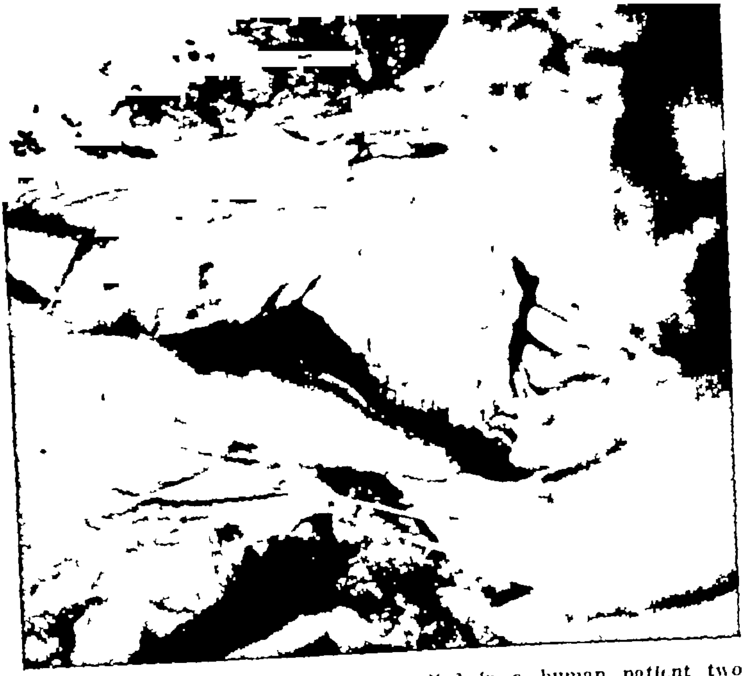


Fig 22—Appearance of pericardial hammock applied in a human patient two days after placement

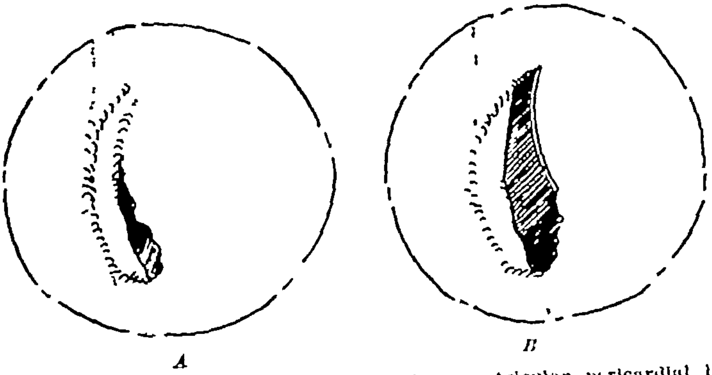


Fig 23—*A* Ten months after placement of transventricular pericardial hammock for mitral regurgitation at reoperation for symptoms of mitral stenosis the somewhat shrunken graft was found adherent to the ventricular aspect of the valve edges *B* Commissurotomy resulted in mobilization of septal leaflet from graft with relief of stenosis and without restoration of regurgitation Graft remained attached to free edge of mural leaflet adding needed tissue in its retracted portion

In addition four patients have come to autopsy four months to two and one half years following placement of free intracardiac pericardial sutures One of these is illustrated in Fig 24 *A* and *B* Two others were shown in Figs 14 *A* and *B* and 18 *A* and *B* respectively In all instances the graft was replaced largely by fibrous connective tissue The thicker grafts have shown shrinkage and contraction. The thinner graft was elongated and stretched out. This is in contrast to pedicled grafts which retain much of their histologic structure and characteristically maintain most of their original bulk.

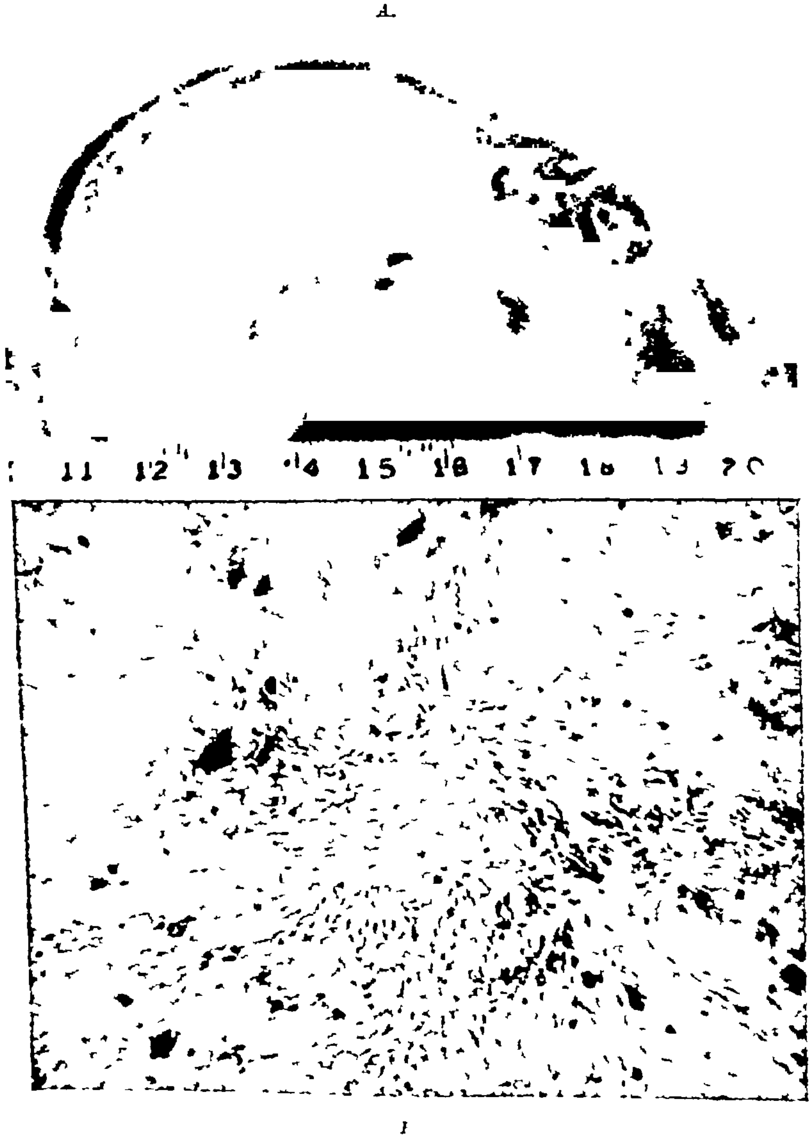


Fig. 21.—A, Appearance of pericardial suture thirty months after placement. B, Photomicrograph of the same.

In summary, we may say that pericardial sutures or grafts placed within the intracardiac chambers do not die or disintegrate. They tend to become replaced partially by fibrous connective tissue and to shrink both in length and in diameter. The latter becomes two thirds to one half of the original measurement although it must be remembered that initially (twelve hours to ten days) these grafts may swell to two to four times their normal diameter and hence may encroach seriously upon the capacity of the chamber in which they are placed.

The application of these observations to the consideration of further use of such grafts is obvious. They cannot be depended upon for prolonged flexible movement. They can be used as suture material or as grafts to add fibrous tissue to the structure to which they are applied. While they shrink significantly, the larger grafts remain of appreciable size at least for a period of two years and presumably indefinitely. Pedicled grafts tend to maintain a fair size and some flexibility permanently.

Fig. 25.—In patients with valve orifices of limited attainable size, direct cross suturing of the valve leaflets may result in the creation of significant stenosis.

CREATED MITRAL STENOSIS

Another very pertinent point is concerned with the possible surgical production of an incapacitating degree of mitral stenosis. While the likelihood of such an occurrence would seem to be extremely remote in patients with widely open valve orifices incompetent chiefly or entirely because of annular dilatation, significant mitral stenosis was produced in several patients with valve openings which were of borderline size even after the performance of an anterior commissurotomy (Fig. 25.).

This experience led to a modification of the concept of actually suturing together the posterior portions of the leaflets in any case where there was even the slightest doubt as to the adequacy of the eventual size of the opening. Instead, a heavy suture of pericardium was placed from the valve substance in the region of the posterior commissure to the free margin of the mural leaflet usually at about its midportion This amounted to an attempt to obliterate the exaggerated concavity of the mural cusp due to fibrosis and retraction

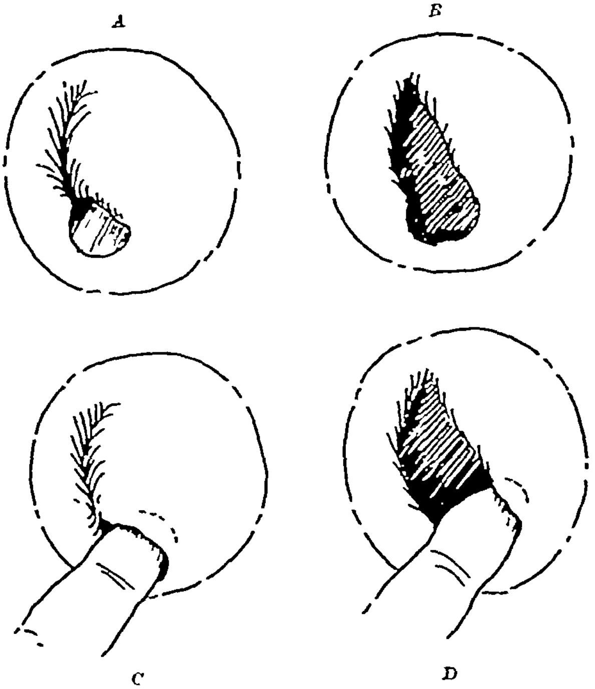


Fig 26—In mitral valves with the usual posterior type of regurgitation sufficiency can be restored temporarily by the placement of the tip of the operator's index finger into the incompetent portion of the orifice This amounts in effect, to the temporary replacement in this region of the actually or relatively lost valvular substance *A* Posteriorly incompetent mitral valve during ventricular systole whether caused by annular dilatation or intrinsic (rheumatic) shrinkage of the leaflets *B* Same valve during diastole provided the septal leaflet retains mobility *C* Blocking of incompetence by the mass or bulk of the operator's finger tip Ventricular systole *D* Adequacy of aperture and valve function provided by residual mobility of leaflets Ventricular diastole

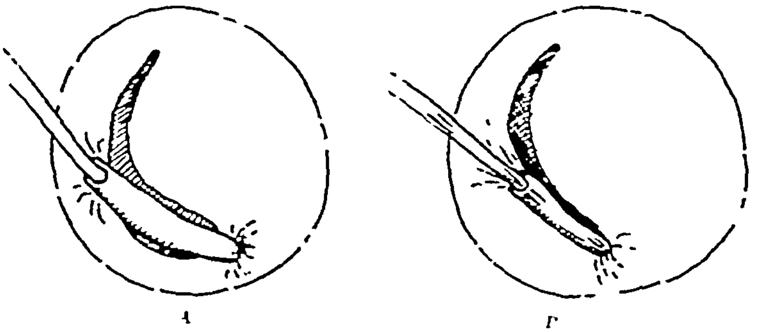


Fig [illegible]—Addition of [illegible] by applying a thick pericardial strip to the deficient posterior leaflet *A* Simple addition of tissue to incompetent portion of the valve *B* Eventual contraction of graft tissue will reduce the area of incompetence

in this portion of its margin by adding new grafted tissue to its free edge This application of new tissue permitted unhampered movement of the septal leaflet while the valve opening remained nearly as large as before In effect the result aimed at was similar to that accomplished temporarily by placing the intracardiac finger tip within the posterior incompetent portion of the valve orifice (*Fig. 26 A-D*). Such digital tamponading of the incompetent posterior portion of the valve may restore complete competence, abolishing the regurgitant jet, without causing significant obstruction of the valve channel. Unfortunately the transventricular suturing technique limited the size of the pericardial suture which could be used conveniently. Hence, the regurgitation merely was reduced in many of these cases and not completely abolished. The clinical result obtained in these individuals was about proportional to the technical achievement with regard to valve function (Fig. 27, *A* and *B*). Table IV illustrates the physiologic changes in E. N. 10 months after performances of such a commissurorrhaphy.

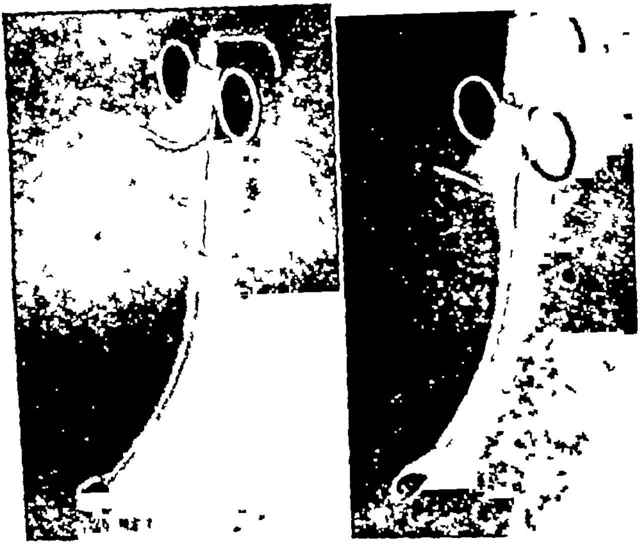
TABLE IV PHYSIOLOGIC DATA ON CASE E. N.

	PREOPERATIVE (12/9/53)		POSTOPERATIVE (9/9/54)	
	REST	EXERCISE	REST	EXERCISE
1 Oxygen consumption (c.c./min.)	216.8	-	202.1	400.9
2 A-V oxygen difference (vol. %)	4.1	-	4.0	5.8
3 Cardiac output (L/min.)	5.3	-	5.1	6.9
4 Cardiac index (units/min./M²BS)	3.9	-	3.4	4.6
5 Pressures (mm. Hg)	—	-	-	-
a "Pulmonary venous capillary"	(30)	-	(13)	-
b Main pulmonary artery	$\frac{60\text{-}75}{20\text{-}30}$ (43)	-	$\frac{32\text{-}38}{0\text{-}8}$ (27)	$\frac{50\text{-}54}{10\text{-}12}$ (27-30)
c Right ventricle	—	-	$\frac{34}{0}$	-
d Right atrium	—	-	(2)	
e Brachial artery	$\frac{120}{70}$ (80)	-	$\frac{100}{88}$ (64)	
f Peripheral oxygen saturation (%)	90.9%	-	92.9	94.7
g Pulmonary arteriolar resistance (dynes sec. cm.)	—	-	220	-

Figures in parentheses refer to mean pressures.

SUTURING OF THE VALVE BY THE AURICULAR APPROACH

In the summer of 1953, one of us (W. L. J.) developed an instrument embodying the principle of the "looper" which is used in the hosiery industry to sew the toes on ladies' stockings. This instrument was designed to permit suturing of the mitral valve by a purely transatrial approach being inserted along the operator's intracardiac index finger through the opening in the left auricular appendage. Subsequent modifications of this instrument notably by two of us (W. L. J. and A. E. B.) have culminated in the "mitral stitcher" (Fig. 28 *A* and *B*) which is a reasonably satisfactory instrument for this purpose. Since this method of valvular repair has become possible very striking improvement in the operative course and mortality and in the clinical results have become apparent in these cases.



A *B*

Fig. 28.—Improved mitral stitcher. *A*, open; *B*, closed.

APPLICATION OF A TRANSVALVULAR PERICARDIAL DIAPHRAGM

Most of those who have investigated the problem of mitral insufficiency clinically[1, 2, 4, 18] have come essentially to the same conclusion that living or prosthetic tissue must be supplied in such a way as to add new substance to the free edge of the actually or relatively retracted posterior portion of the mural leaflet. It was pointed out by one of us (H. T. N.) that a nonmobile pericardial tube placed diagonally across the posterior half of the valve orifice in close proximity to this cusp would accomplish the desired purpose. Furthermore the very secure attachment of such a graft at the sites of ventricular wall penetration would obviate the risk of tearing the valvular substance when it is thin and nonfibrotic. Even complete retraction of the leaflet edge or commissural tissue against the inner ventricular wall (which would render accurate valve cusp penetration extremely difficult) would not hamper the placement of such a transvalvular pedicled tube or diaphragm. Since the tube may be caused to traverse the ventricular wall in an oblique fashion it can be placed at any level up to the actual valve ring without endangering the circumflex coronary artery which lies upon the latter. Should one such graft prove incapable of blocking all of the regurgitation a second one may be applied alongside it by parallel penetration of the ventricular wall (Fig 29) Weight was lent to the validity of this hypothesis by the suggestion that this actually had been accomplished inadvertently in the case illustrated in Fig 23

In the implementation of this concept, 7 patients have been operated upon in this manner While the regurgitation was abolished completely in only 2 instances it was reduced significantly in all There was no abnormal tendency to bleeding, there were no operative deaths, and all operated patients subsequently have manifested definite clinical benefit

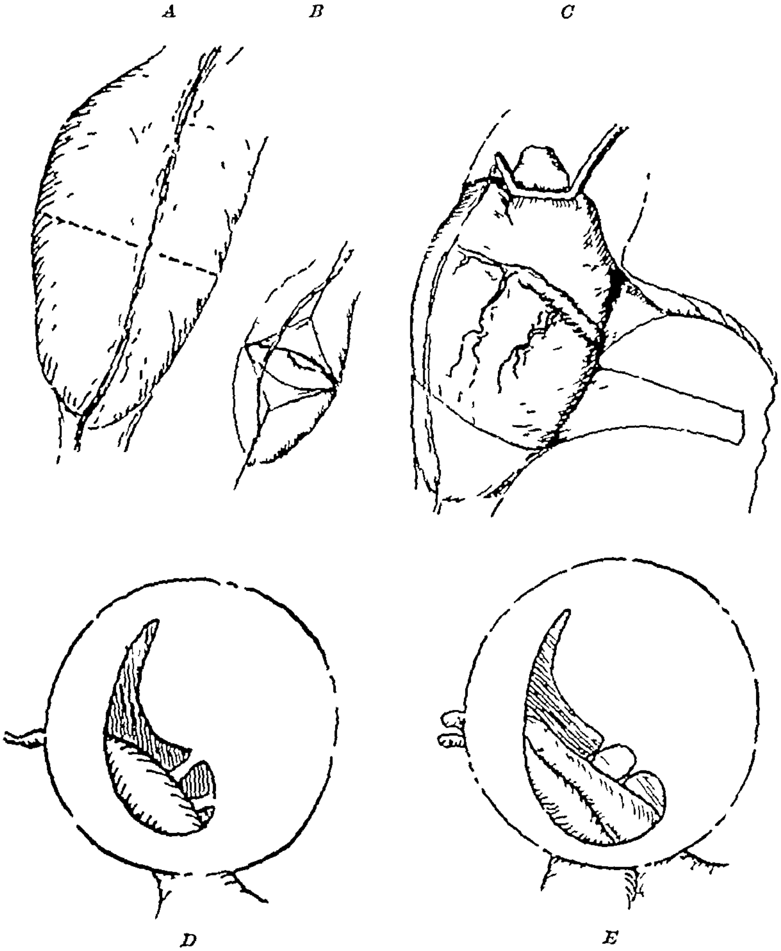


Fig 29 —*A* Preparation of two tapering posteriorly pedicled pericardial tube grafts Line of proposed pericardial incision *B* Left phrenic nerve is mobilized completely before opening pericardium *C* Longitudinal twisting of grafts causes them to assume a tubular character The epicardial surface must be made to lie on the outside *D* Transvalvular graft placed to form a diaphragm of living tissue across the concavity of the relatively or actually deficient mural leaflet *E* When a single such graft is not large enough to abolish or nearly abolish the regurgitation a second one may be placed alongside it (through different myocardial punctures) to widen the restraining diaphragm

LEFT VENTRICULAR BY-PASS DURING SURGERY

This added ease and facility of intracardiac manipulation has been matched by another important development—the availability of a simple and satisfac tory method of partial left ventricular by pass by use of the Gemeinhardt pump (Fig 30 A and B) The construction of this pump and its experimental use and testing were accomplished by two of us (W G and W L J) Its specific clinical use has been reported in detail elsewhere[19, 20]

This pump is connected to the circulation by two cannulae one inserted by way of a left superior pulmonary vein puncture into the left atrial chamber while the other is inserted into the aorta by way of an incision into the left subclavian artery While it is necessary initially to fill the pump with 150 c c of saline or blood and while heparin in a dosage of 1 2 mg per kilogram is necessary to inhibit coagulation these quantities are much less than are required for any other extracorporeal circulatory apparatus of which we are aware

The Gemeinhardt pump may be used in any patient with borderline circulatory competence to assure an effective output of oxygenated blood into the aorta at a pressure sufficient to maintain coronary and generally bodily needs Thus it is rendered possible to perform manipulations within the heart with the aid of this pump which could not be tolerated otherwise Dodrill[10, 21] has reported the implementation of a similar concept with a pump of different design It is believed that many others will adopt this principle in the future as progressively more difficult types of cardiac surgery are attempted in borderline cases in which the patient s circulatory reserve may be insufficient to carry him successfully through the operation without auxiliary support

With the advantages of the availability of the mitral stitcher and of the Gemeinhardt pump we have been able to expand our surgical program significantly to include cases which were previously considered inoperable or at least incorrectible

PRESENT SURGICAL TECHNIQUE

The patient is studied and prepared in the same manner as other cases for mitral surgery Since 71 3 per cent of these patients have chronic atrial fibrillation nearly all will be on full digitalis maintenance After compensation has been established and clinical improvement has reached a maximum the patient is brought to the operating room and is anesthetized preferably in the usual manner This is the combination program of intravenous Pentothal and procaine with endotracheal oxygen which has been described by Keown Grove, and Ruth[7]

The patient is placed in the true lateral position with the left side up The usual curved posterolateral incision is made beginning in the midclavicular line below the breast and extending below the lower angle of the scapula and up posteriorly to the level of the spine of the scapula The muscles of the chest wall are divided in the line of the skin incision and all bleeding points are clamped and ligated or coagulated with the high frequency current

The fourth intercostal space is opened from the internal mammary vessels to the transverse processes of the vertebrae If no pleural adhesions exist

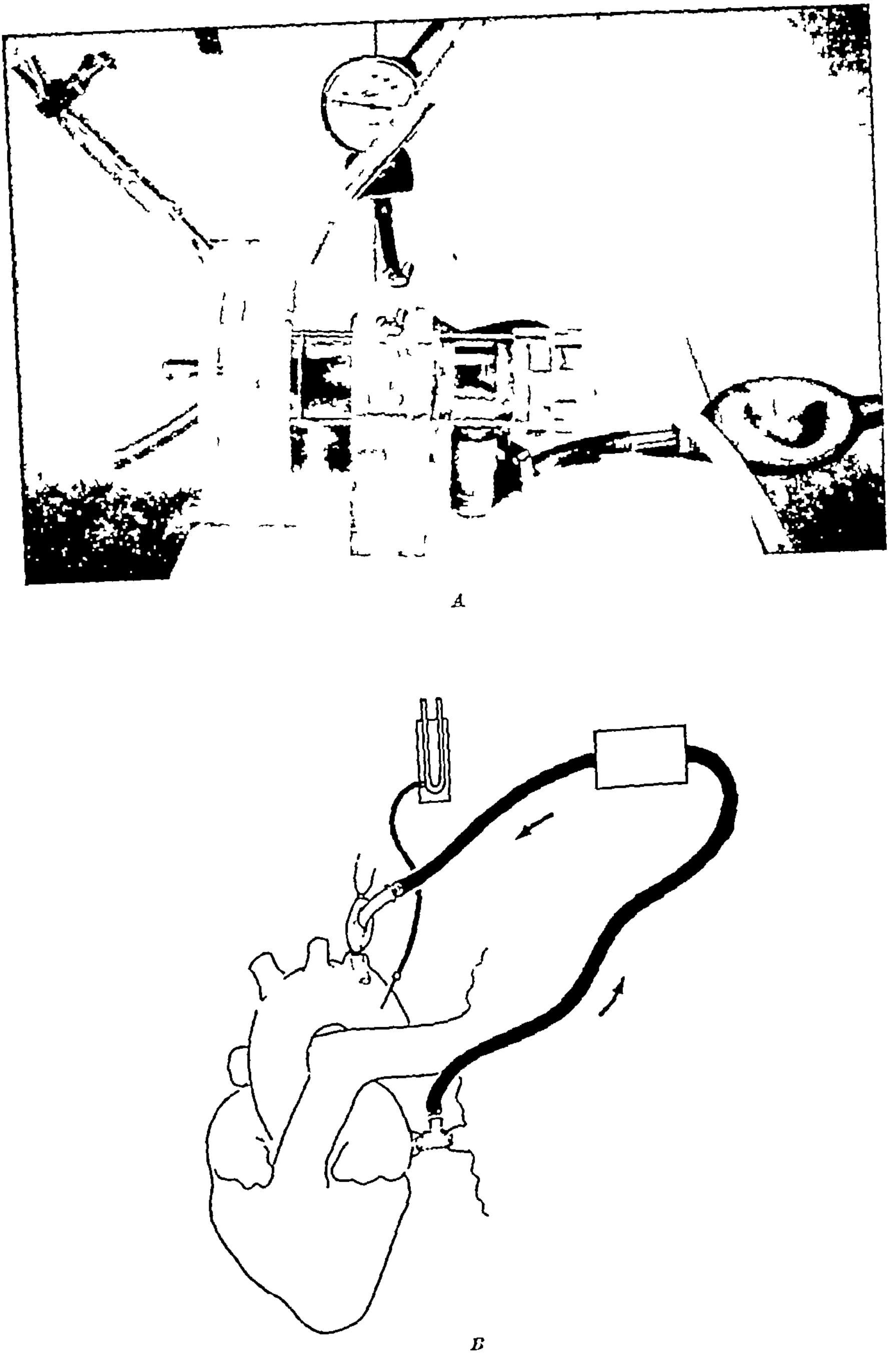


Fig. [illegible].—Gemeinhardt pump. A, Essential parts of the pump. It is effectuated by compressed air from a compressor situated beneath table top. B, Diagram showing proposed connections of pump to circulation.

the lung is compressed posteriorly. If there is pleural symphysis, the upper lobe is completely mobilized but the lower is permitted to remain adherent.

The pericardial sac is opened. The surface of the usually dilated atrium is palpated to detect the pathognomonic systolic thrill of mitral insufficiency. Occasionally it is absent even when a significant degree of regurgitation exists. When free sutures of pericardium are to be used, the sac is incised longitudinally. If a transvalvular pedicled diaphragm is to be applied, the sac is incised transversely after mobilizing the phrenic nerve. Since this frequently cannot be determined in advance, it is suggested that a very limited pericardial opening be made at first. Then, regardless of what is determined after intracardiac exploration, an advantageous extension of the pericardial opening will be feasible.

USE OF THE GEMEINHARDT PUMP

At this point the patient's condition and tolerance to surgery is evaluated. If it seems probable that his blood pressure and other vital phenomona will be well maintained without the aid of a partial by-pass pump, the definitive procedure is begun cautiously without it. If the blood pressure has dropped significantly or if there are other evidences of circulatory inadequacy, the pump is attached quickly to the vascular system by inserting a cannula into the left atrial chamber by way of a puncture in the anterior surface of the left superior pulmonary vein. The branches of the vein are encircled twice distally with a heavy silk ligature which is tied only moderately tightly. A similar ligature is placed about the proximal portion of the vein to secure the cannula in place as well as to prevent leakage about it. Heparin, 1.2 mg. per kilogram of body weight, is administered intravenously and blood is permitted to enter the apparatus to fill it up to the filter and to expel any inadvertently trapped air bubbles.

The left subclavian artery is mobilized to its origin. The proximal portion of the arterial wall is encircled with a heavy silk purse-string suture which picks up the adventitia. The distal portion of the artery is ligated with umbilical tape which is not tied sufficiently tightly to injure the intima. The proximal portion of the vessel is obstructed with a pair of toothed Potts ductus forceps and a longitudinal incision is made in its exposed surface. The lumen is flushed with dilute heparin solution and the arterial cannula is inserted into its lumen (directed proximally) as the clamp is removed until the beveled end of the cannula lies within the aortic lumen. The circumferential ligature placed about the proximal portion of the vessel is tied moderately tightly to restrain bleeding and hold the cannula in place.

Arterial blood is admitted to the pump, expelling any entrapped air. Now the pump mechanism is set into action and its speed is increased gradually.

A direct mean manometric reading may be obtained from any conveniently located peripheral artery, even from the aorta, by direct needle puncture and the use of a mercury manometer. Alterations in the rate of pumping and the use of any vasopressive agent are conditioned to the level of the mean blood pressure. This usually should be kept within a range of 90 to 120 mm. mercury

DEFINITIVE SURGERY OF THE VALVE

Whether the pump is to be used or not the distal portion of the usually greatly dilated left auricular appendage is encircled with a purse-string suture. This is incorporated within a Rumel-Belmont tourniquet. The appendage is clamped off and the terminal end is incised for a distance of 2 cm. Its cavity is flushed. The index finger of the right glove is amputated and the bare finger tip is inserted between the lips of the appendageal opening. As the occluding clamp is removed, the finger is passed well into the left atrium, hemostasis being provided by tension on the purse string by way of the tourniquet.

The valve is sought immediately, and its structure is explored. The existence and relative amount of the insufficiency is estimated from the size and character of the regurgitant jet. The size of the valve orifice, the presence and type of any coexistent mitral stenosis, the localization of the jet with relation to the valve commissures, and the flexibility of the leaflets must be estimated carefully. The presence of any calcification and its amount and character are determined.

After a thorough exploration of the valve the operator will have some idea of the type and amount of the insufficiency, the necessity and probable success of corrective surgical measures, and the advisability or necessity of performance of a preliminary commissurotomy. If the latter is required, it is performed at once in order to enlarge the valve opening and to improve its functioning. Sometimes a properly performed commissurotomy alone is all that is necessary to restore a considerable degree of valve competence. If this effect is sufficient, no further corrective surgery is indicated.

However, in most instances the insufficiency will persist. Then the operator may gently insert his finger tip into the incompetent portion of the opening to determine whether there is a relative or actual lack of valvular tissue posteriorly or elsewhere. In many cases the cross-sectional area of the finger will add sufficiently to the substance of the retracted mural leaflet to restore complete competence without seriously blocking the size of the valve aperture during diastole. This phenomenon is dependent upon the existence of an adequately functioning septal leaflet (see Fig. 26).

In certain cases one leaflet (usually the mural) will be determined to be suspended at a higher level than the other. This is suggestive of unequal tendinous suspension of the two leaflets and indicates the advisability of placement of an 'artificial' chordal suspension as previously described. Digital depression of this higher leaflet usually will bring about perfect valve apposition in these cases.

In most cases the leak will be found to be located posteriorly and one of the forms of direct repair by the use of a free or a pedicled pericardial graft will be deemed advisable if it is over 2 plus in magnitude. Having estimated with the finger the amount of the lack of valvular substance, the finger is removed from the heart and the appendage is clamped.

TRANSAURICULAR SUTURING OF THE VALVE

A full length fairly broad strip of the pericardial sac is removed from the region anterior to the left phrenic nerve. Great care is taken to control any bleeding from the remaining cut pericardial edges or from the dissected mediastinal tissues.

When the valve is of firm structure, the orifice is large, and there appears to be an adequate quantity of valvular tissue for suture approximation without tension, a 3 cm. wide strip of pericardium is obtained to be used as an oblique approximating suture between the portions of the valve edges making up the posterior peripheral segment of the orifice. Both ends of the strip are cut in tapering fashion and an "eye" is created in one end.

When it is felt that because of an actual or relative lack of valvular tissue there is a necessity for the application of additional living substance to the posterior incompetent portion of the valve, provision is made for it in either of the following two ways. If the pericardial strip is deemed to be sufficiently long, it is trimmed so that it is 3 cm. wide except in the very middle portion where all excess pericardial tissue is permitted to remain attached. This is rolled or folded about the central axis of the strip in such a way as to create a mass of pericardial tissue 2 to 3 cm. long and perhaps as thick as a man's finger. This is to be placed on the ventricular aspect of the valve *in* its incompetent portion. Since it will swell initially and shrink eventually, considerable care should be devoted to establishing the correct size of the mass or "plug." The selected size is definitely established by the application of securing sutures of fine arterial silk. Both extremities of the pericardial strip are beveled. No "eye" is made.

On the other hand, if the length of the available pericardial ribbon seems short in comparison with the size of the left atrium, it simply may be trimmed to a 3 cm. width with tapering extremities and an "eye" in one end. Then an additional free strip of pericardium may be "impaled" upon the tapered one by passing the latter through each of a longitudinal row of openings made in the former one. This produces an "accordion pleated" mass which can slide freely upon the length of the tapering strip. (Fig. 31, *A-C*.)

Now, having prepared a suitable "pericardial suture," the bare right index finger is returned to the left atrial chamber. The left-sided mitral stitcher is threaded with a heavy nylon suture (No. 2) and is inserted into the heart by passage along the index finger and under the anterior lip of the incised auricular appendage. The open instrument is applied to the free margin of the valve orifice *in* such a way that the suture-bearing "beak" becomes engaged beneath the mural leaflet. When simple suture obliteration of the posterior incompetent segment of the valve is all that is intended, the beak is placed at a point two-thirds of the distance from the anterior commissure to the posterior (junction of the posterior and middle thirds). When it is intended to apply additional substance to the valve, the site of mural leaflet penetration is selected as that where the leaflet retraction begins to become apparent. This will usually be about at the mid point in the length of this leaflet.

Having placed the beak properly under the leaflet, the ends of the nylon suture are held under slight tension and the spearlike sliding blade is advanced by pressure of the thumb of the operator's left hand It pierces the valve substance, creating a 3 mm long slit and engages the nylon suture held in the beak within the slotted groove on its inner edge

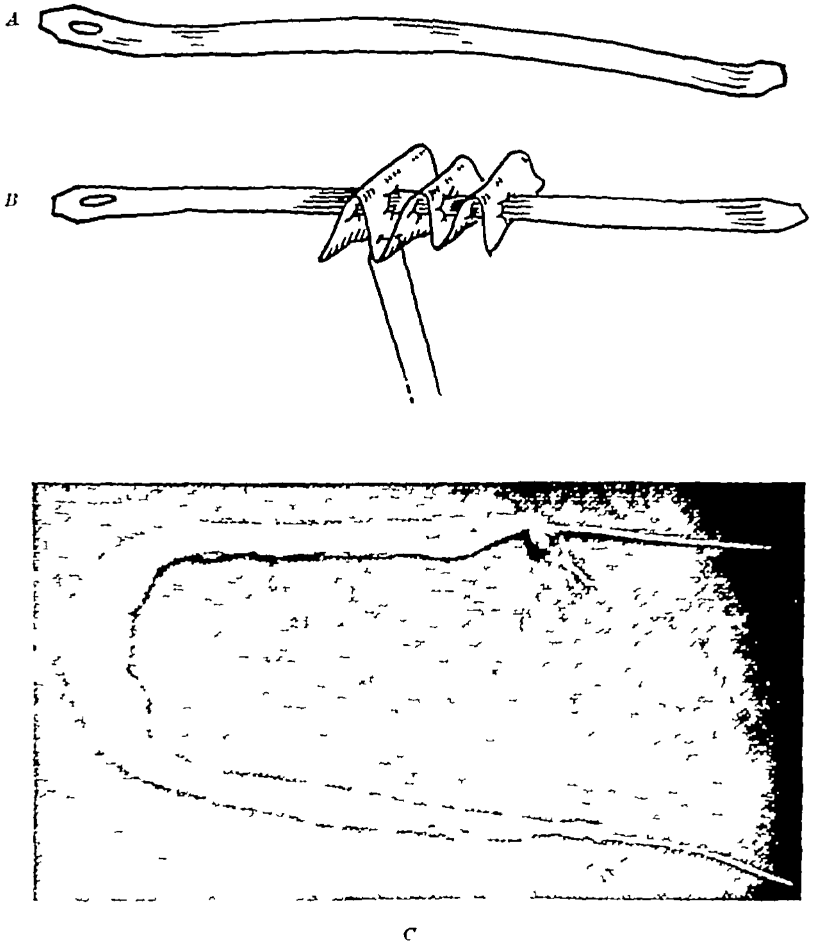


Fig 31 —*A* Simple pericardial suture These should be made 3 cm in width the full apicobasal length of the pericardium and should be made to taper at their extremities *B* To supply additional graft material especially with a small graft a 1 cm wide additional pericardial strip may be impaled by the original one through a row of longitudinal punctures made 1 5 cm apart This produces an accordion pleated mass which slides freely on the basal suture strip A simple cotton suture loop should be placed through the substance of the sliding mass to insure against loss into the blood stream in case the nylon sutures become detached from either pericardial end *C* Photograph of pericardial suture made with central thickening No noose may be formed with this type of graft

By backward traction upon the sliding blade a loop of nylon suture is drawn up into its sheath and finally well out of the heart (at least 8 to 10 cm out of the instrument) The sliding blade is detached from the suture loop and the instrument is disengaged from the valve and removed from the heart One loop of nylon suture and two free ends now emerge from the opening in the left auricular appendage The former emerges from the atrial aspect of the mural leaflet of the valve while the latter traverses the natural valve orifice to penetrate the ventricular aspect of the mural leaflet Each of these three suture ends is fixed *without tension* to the drapes with fine hemostatic clamps

Now if the posterior peripheral valve segment is merely to be sutured closed the threaded right-sided "stitcher is inserted into the heart and a similar nylon suture is placed at the selected point (somewhat more posteriorly than at the junction of the posterior and middle thirds) in the substance of the septal leaflet The loop and suture ends are brought out of the appendage in fashion the same as the previously placed ones Such cases will be those with very large valve orifices and some of them may also require the placement of a second more posteriorly located approximating suture

When the over-all valve size is less adequate and when one only desires to add extra living tissue to the retracted mural leaflet the left-sided stitcher is rethreaded and used This time it is inserted into the left atrium on the palmar surface of the intracardiac finger which is turned in a pronated position care being taken not to entangle with the previously placed nylon sutures The "beak ' is engaged under the posterior commissural tissue in such a way as to be assured that the graft tissue mass will be well applied to the contracted concave free margin of the mural leaflet The sliding blade is driven home perforating the commissural tissue and engaging the suture loop which is then drawn out of the heart The remainder of the instrument is disengaged from the valve and withdrawn Again the loop and two ends of nylon emerge from the appendage and are tacked down without tension to the available wound drapes to avoid possible entanglement and subsequent confusion (Fig 32 *A-D*)

Now the tapering extremities of the pericardial strip each are attached to one of the two pairs of free nylon ends which pierce opposite valve leaflets (or the mural leaflet and the commissural tissue)

Traction is now cautiously made upon the appropriate sides of the two nylon loops until the free ends attached to the pericardial strip become drawn into the heart Davidson[2] has aided greatly in the application of this technique by suggesting differential staining of half lengths of each of these nylon sutures

The traction must never be very forcible nor must undue tension ever be permitted lest the valve leaflets become 'sawed through Judicious release of the purse string tension and manipulations with the intracardiac finger aid greatly in the application of the graft to the ventricular aspect of the valve

If the heart action becomes weak at any time it probably is related to temporary aggravation of the insufficiency by distortion of the valve by the traction of the nylon or pericardial suture It can be alleviated by release of the traction and by placement of the finger tip into the incompetent portion of the valve orifice to improve its function until full cardiac vigor is restored When using the Gemeinhardt pump to maintain the circulation maintenance of the intrinsic cardiac function is not quite so important during the definitive surgical manipulations since it may be replaced mechanically

Finally, the pericardial ends having traversed the valve orifice will reach the puncture sites in the valve from the ventricular aspect. They may meet with considerable resistance to further passage because of the smallness of the perforations. However, if the entire graft is inserted into the left atrial chamber, to reduce external frictional drag, and if the nylon suture is pulled successively in different directions (cephalad, caudad, anterior, and posterior)

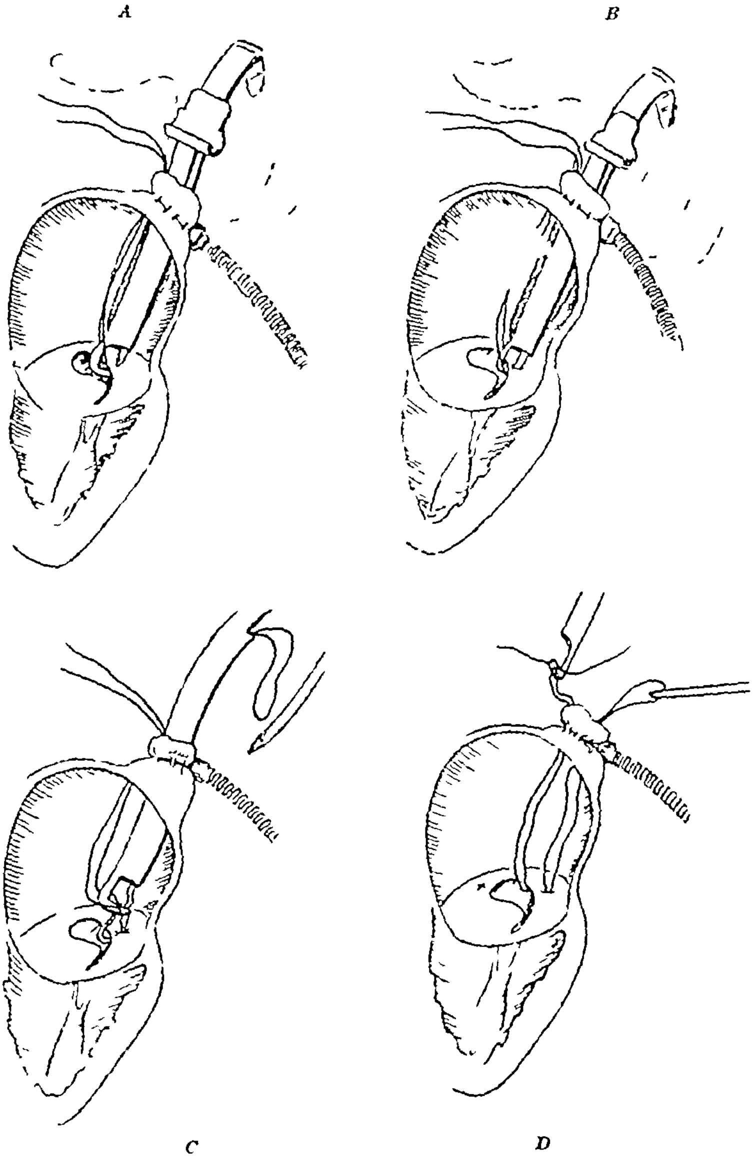


Fig. 3.—Technique of using the mitral stitcher. The stitcher has been inserted into the left atrium alongside the operator's index finger. *A*, Engaging the beak threaded with nylon under the free edge of the mural leaflet. *B*, Advancing the sliding blade so that its slotted spear point pierces the leaflet and picks up the suture held in the beak. *C*, Removal of the sliding blade withdrawing 8 to 10 cm. of the suture loop from the instrument. *D*, After the sliding blade is detached, the rest of the instrument is removed from the heart.

with a release of tension between each change of traction the tapered graft ends will soon penetrate the punctures in the valve, will emerge from the heart and the graft will be in place.

If the type and size of the graft have been selected properly and placement has been correct, the regurgitation should be nearly or completely abolished at once, especially if gentle traction is made upon the nylon ends. This slight tension may be made permanent by passing the intact tapered end of the suture through the previously made "eye" in the other end in the case of the simple approximating pericardial suture and in the case of the suture with an "accordion-pleated" impaled pericardial mass. The fine cotton suture loop which will have been placed through this "impaled" mass to prevent its possible loss into the blood stream (guard against the possibility that one of the nylon sutures might become detached from one of the pericardial ends) is now cut and removed. When using the pericardial suture with the central rolled pericardial thickening no noose technique is possible and both pericardial ends must be brought out separately from the appendage. (Fig. 33 *A-F*.)

The mitral insufficiency having been largely or completely corrected as indicated by the lessening or abolition of the regurgitant jet and an adequate residual valve orifice having been maintained, the procedure is terminated. The finger is withdrawn from the heart and the appendageal stump is ligated and oversewn. The oversewing sutures are carefully guided through the substance of the emerging pericardial end or ends. No great amount of tension upon them is permitted.

TRANSVALVULAR APPLICATION OF A RESTRAINING PERICARDIAL DIAPHRAGM

Whenever there is any question as to adequacy of the size of the perhaps surgically enlarged valve orifice, when the valve leaflets are thin and presumably fragile or when a portion of the mural leaflet or the posterior commissural tissue is retracted against the ventricular wall, even oblique placement of a free pericardial suture is contraindicated or technically not feasible. Here a transvalvular pericardial tube diaphragm should be employed.

The operator, after exploring the valve and determining upon the indicated course of action, removes his right index finger from the heart and temporarily clamps the left auricular appendage. He then passes to the opposite side of the table and, after the patient has been rotated more nearly into the prone position, introduces his ungloved left index finger into the left atrium by way of the appendage. The terminal edge of a specially constructed semimalleable probe* is threaded with heavy nylon thread, care being taken that the latter does not become twisted about the instrument. Guided by the intracardiac finger, the probe tip is inserted through the ventricular wall in a diagonally upward fashion beginning at a point 1 cm. below (toward the apex) the atrioventricular sulcus over the midpoint of the attachment of the mural leaflet. As the probe tip enters the heart, the intracardiac finger tip guides it close to the free edge of the mural leaflet and across the posterior incompetent portion of the valve orifice to the region of the posterior commissural tissue.

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*[illegible] Obtainable from [illegible] Pilling & Son Co., Philadelphia, [illegible] transvalvular graft

The probe then is caused to penetrate the posterior ventricular wall in a direction diagonally downward (toward the apex), either just above and practically through the annular attachment of the commissural tissue, or preferably, just to the ventricular side of this attachment.

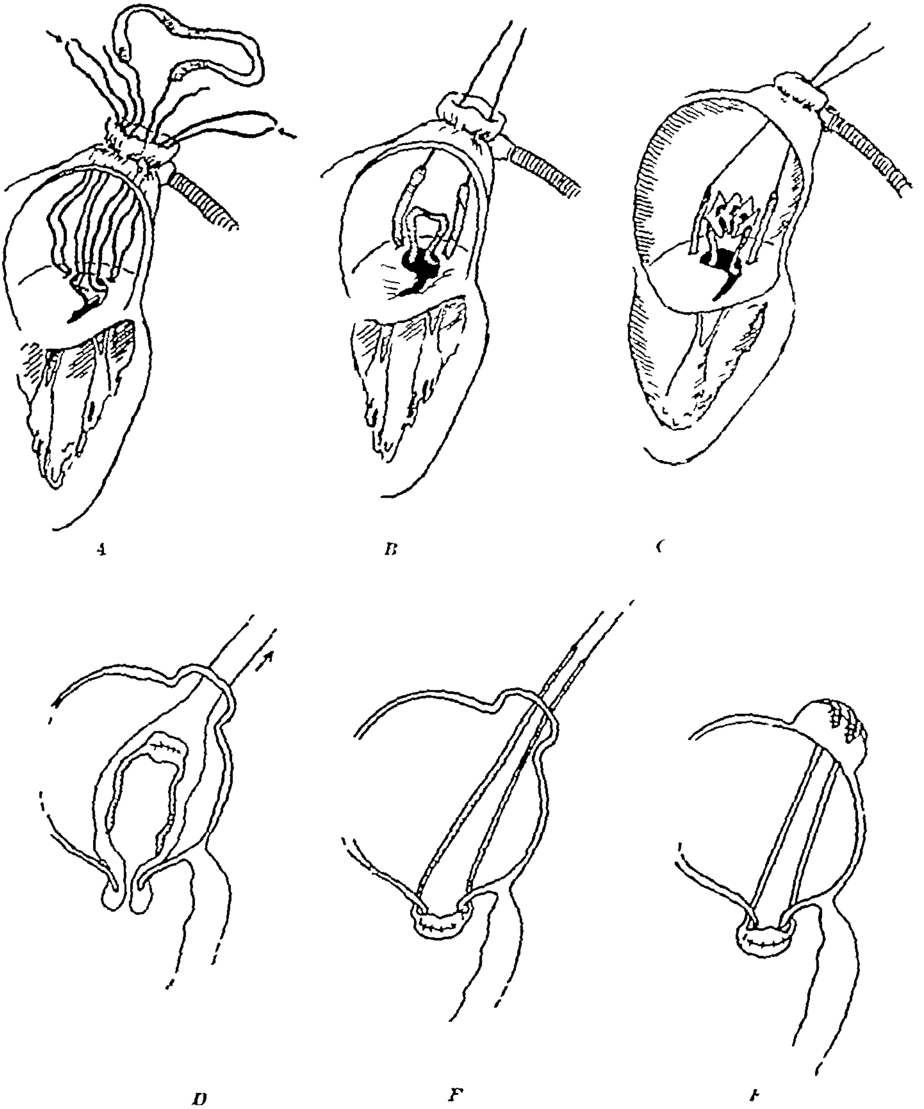


Fig. 33.—A, Replacement of the nylon sutures with a pericardial strip. Attachment of pointed extremities of pericardial graft (one of the three types described) to one of each of the central pairs of free nylon sutures. B, By traction upon the emerging closed suture loops the ends of the pericardial strip are caused to enter the heart and to pierce the valve from below. C, Impaled pericardial suture piercing the valve. D, Pericardial strip with thickened central portion piercing valve leaflets. E, Pericardial ends emerging from appendage. F, Attachment of free ends of pericardium to appendageal stump.

The probe tip can be felt digitally or can be seen by an assistant bulging the myocardial tissues before it actually penetrates the epicardium. If it appears about to emerge in close proximity to an important coronary arterial branch, it is withdrawn slightly and redirected to emerge at a more favorable site. Then the suture borne in the terminal eye is grasped and held, while the probe is drawn back and out of the heart.

Ten or more centimeters of the suture are drawn out of the heart posteriorly and the loop is divided into two separate strands. One of these is set aside as a "spare" in case the other should become detached from the end of the graft. A circumscribing mattress suture of No. 1 braided silk on an Atraumatic R curved needle is placed in the myocardium about the site of posterior suture emergence at a distance of 6 to 10 mm. A single knot throw may be placed to restrain bleeding from this puncture wound. The anterolateral puncture site may be treated in similar fashion.

If this procedure has been chosen initially, the pericardial sac will have been incised transversely (after fully mobilizing the left phrenic nerve) at a level close to the atrioventricular junction posteriorly. Then, two suitable tapering pericardial tubes pedicled posteriorly will have been prepared. If the pericardial entrance has been of any other type, the preparation of even one satisfactory pedicled pericardial tube may prove difficult but usually can be accomplished. Free grafts are much less desirable because they shrink more. All excessive pericardial fat is removed. In order to obviate the use of sutures the pedicled tube is shaped by twisting it loosely upon its long axis, taking care that the smoother epicardial surface comes to lie externally. A tube 12 or more centimeters long prepared from a tapering strip of pericardium 6 cm. wide at its base and smoothly tapering to its tip (not over 1.5 cm. width of pericardial tissue here) is quite satisfactory.

The tip of the graft is attached securely (by suturing) to one of the two strands of nylon emerging from the heart wall posteriorly. The intracardiac finger tip lifts up the transvalvular portion of the sutures to cause the direction of the transmyocardial traction to follow the desired oblique course both anteriorly and posteriorly. Now the appropriate suture end emerging anterolaterally is drawn upon. The second suture strand acts as a "spare" to be utilized only if the graft should become detached from the first.

The tapering end of the graft penetrates the posterior ventricular wall, traverses the posterior half of the valve orifice, dips under the mid point of the free edge of the mural leaflet and emerges from the lateral left ventricular wall. The intracardiac finger determines the point at which a sufficiently large bulk of graft tissue lies within the incompetent portion of the valve orifice. Should weakening of the cardiac activity occur at any time, further manipulation of the probe or graft should be held in abeyance until improvement in function takes place. Placement of the finger tip within the incompetent portion of the valve orifice, as described previously, will tend to bring about improvement by temporarily abolishing the valvular leak. After restoration of cardiac vigor has been accomplished the definitive reparative manipulations may be resumed cautiously.

The degree of correction of the insufficiency finally achieved may be estimated digitally by evaluating the extent of reduction of the regurgitant jet. The unhampered action of the septal leaflet and the size of the remaining valve aperture should be noted at the same time. If it is determined that another tube diaphragm is necessary to abolish the leak, the procedure is repeated and a second graft is placed alongside the first but through slightly different puncture sites.

The procedure is terminated by tying the posterior mattress suture securely about the graft after removing the second transcardiac nylon ('spare') suture. Usually, we prefer also to attach the mattress suture to the graft substance by direct suturing. It is well to have retained some loose or excess graft tissue posteriorly so that the cardiac movements will not make traction upon the graft and, hence, will not tend to cause bleeding from the site of entrance into the ventricle.

The anterior end of the graft is fastened in a similar fashion using a mattress suture in the myocardium and affixing it securely to the graft. The end of the latter, if sufficiently long, may be tied into a knot which then is rendered a permanent one by placing transfixion sutures of cotton. Such a bulky knot of living pericardium tends still further to seal the ventricular wound against hemorrhage and to insure against any possibility that the end of the graft might be drawn into the heart by the systolic surge of ventricular pressure against the transvalvular portion of the graft diaphragm.

If the Gemeinhardt pump has been used its action is caused to slow down gradually to permit the left ventricle to take over its full natural burden now much reduced by the effectiveness of the surgery. The atrium is decannulated by cutting the proximal encircling suture about the pulmonary vein and removing the cannula. The central end of the vein is clamped simultaneously and it is flushed with heparin solution and repaired with arterial sutures. Then the clamp and the distal encircling sutures are removed restoring normal pulmonary drainage.

The subclavian cannula is removed after cutting the proximal encircling suture. The vessel may be clamped proximally and repaired by suturing or simply may be ligated centrally and distally.

Chest wall closure is routine using simple water-seal drainage through a fenestrated No. 26 urethral catheter inserted through a stab wound in the left eighth intercostal space, posterior axillary line.

The correction of insufficiency due to unequal suspension of the leaflets has been detailed (Fig. 35, 1-F).

The roentgenograms on two patients treated by valvular suturing are shown in Figs. 36 and 37.

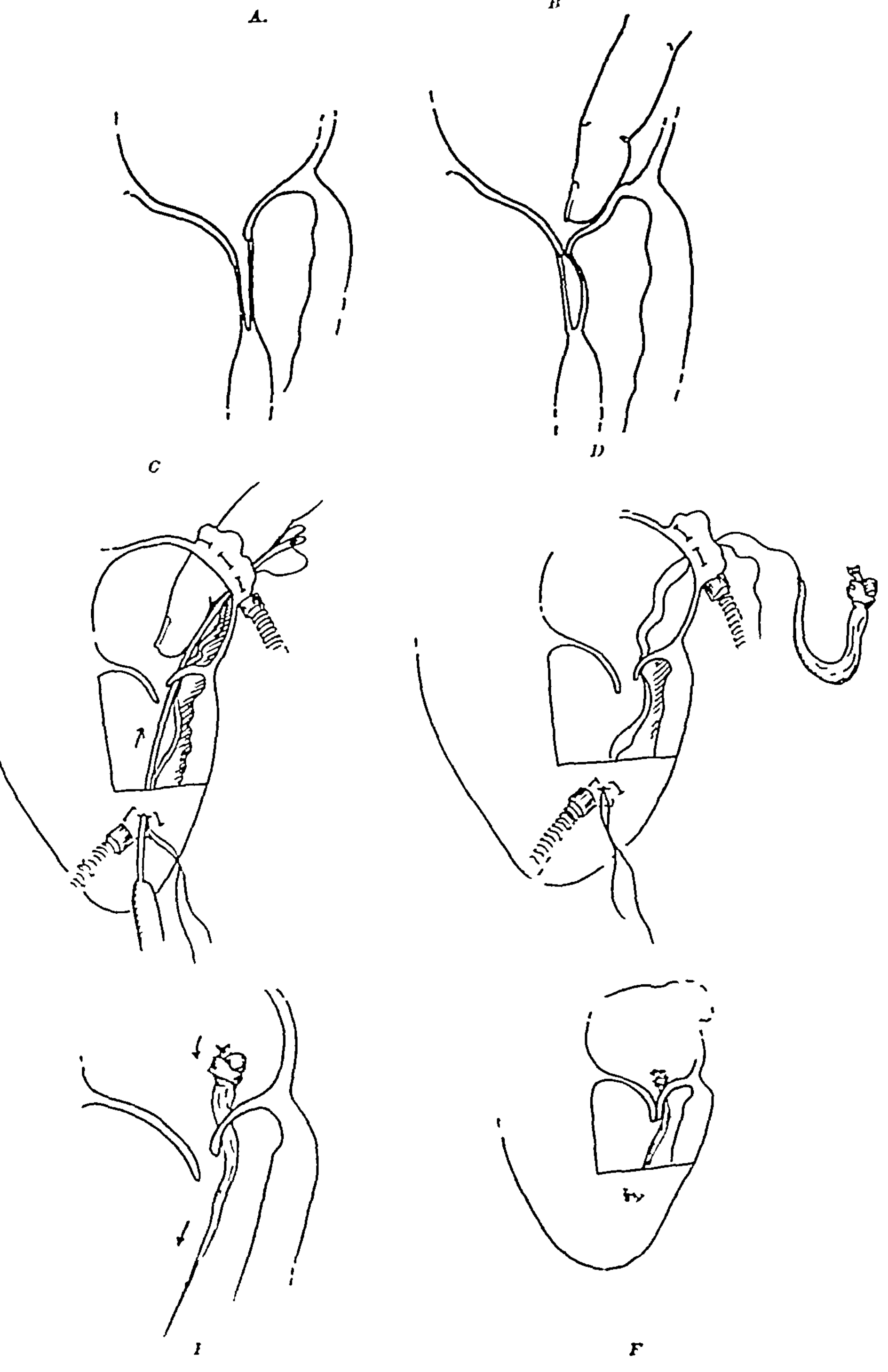


Fig. 21—Jamieson's method of correcting mitral insufficiency due to unequal shortening of supporting chordae. A, Long section of valve showing unequal levels of suspension. B, Temporary restoration of competence by digital depression of the higher leaflet. C, The transventricular [illegible] the eyed probe pierces the higher leaflet and follows the finger to emerge from left auricular appendage. D, Suture grasped, probe withdrawn and the atrial end of the suture is attached to the tapering end of a knotted pericardial graft. E, Pericardial graft drawn into heart. F, End of new support secured to epicardium.

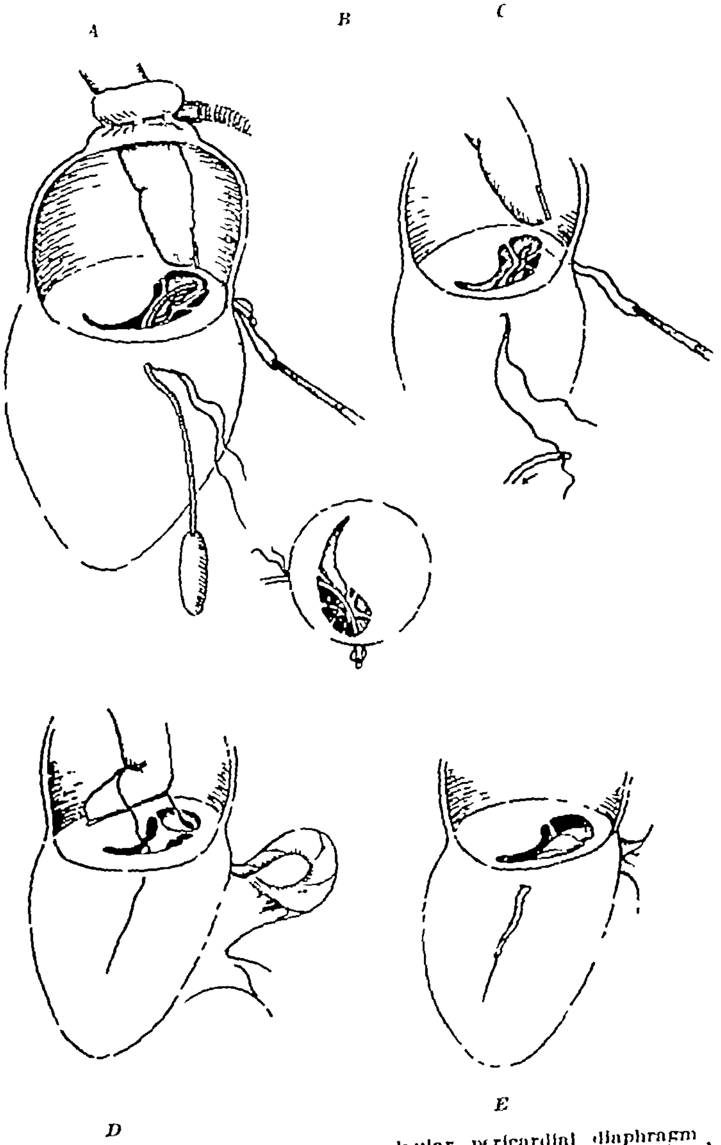
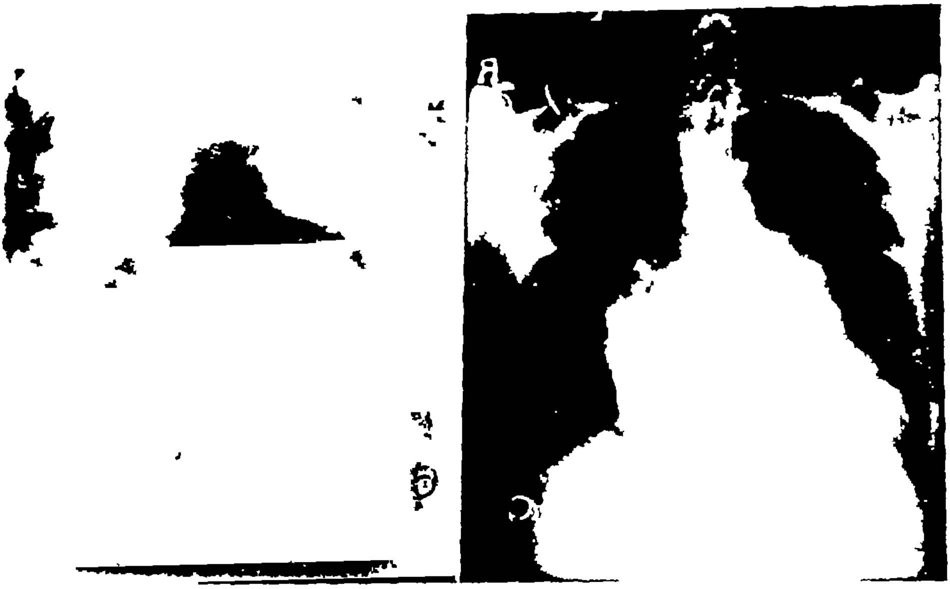
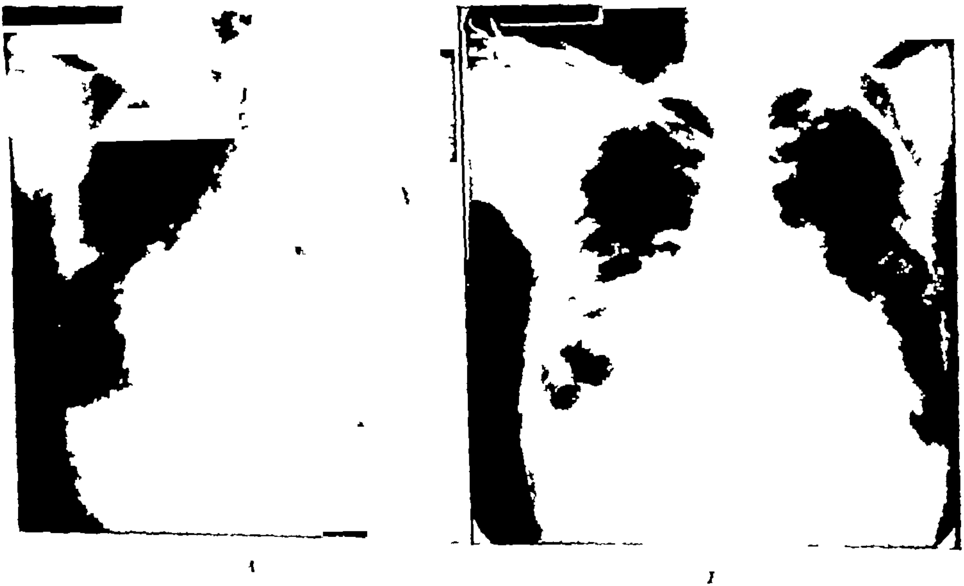


Fig 35.—Steps of placement of transvalvular pericardial diaphragm A, Passage of curved terminally threaded semimalleable probe guided by the intracardiac left index finger through left ventricular wall just beneath middle of mural leaflet diagonally across the posterior portion of the valve orifice and finally through the ventricular wall in the region of the posterior commissural tissue B Top view of course of passage of the probe C Suture borne in tip of emerging probe is grasped and held by an assistant Probe is then withdrawn D After dividing posterior suture loop one end is secured to the tip of the graft the other is retained as a spare The intracardiac finger lifts up the transvalvular suture loop in order to direct the transmyocardial traction along the same lines as the course of the probe punctures E By traction upon the anterior extremity of the suture the graft is drawn through the heart and across the valve orifice until the operator guided by his intracardiac finger is satisfied as to the degree of reduction in the regurgitation If not a second passage of the probe may be required for the placement of a second parallel graft



A *B*

Fig. 36.—*A*, Preoperative roentgenogram in S. A., a 19 year old white man with wide open (4 plus) mitral insufficiency due to annular dilatation. Almost armchair life. Loud long apical systolic murmur. Treated by suture obliteration of posterior peripheral segment of valve orifice with two *simple pericardial sutures*. Regurgitation deemed reduced 75 per cent. *B*, Six months postoperative roentgenogram showing significant reduction in heart size. Clinical improvement has been extremely satisfactory. Much reduced systolic murmur.



A *B*

Fig. 37.—*A*, Preoperative roentgenogram in C. D., a nearly completely incapacitated 24 year old white man with severe predominant mitral insufficiency (3 plus) but some significant stenosis. After anterior commissurotomy and posterior commissurorrhaphy using a large (6 cm. [illegible]) suture to add pericardial substance to the free posterior margin of the mural leaflet, the regurgitant jet was completely abolished. *B*, Three months postoperative roentgenogram shows no apparent reduction in heart size. Nevertheless, there is now only a 1 plus systolic murmur and patient can climb three flights of stairs without difficulty.

The hospital mortality experienced in the treatment of 156 patients with severe mitral insufficiency is presented in Table V.

TABLE V. METHODS OF MANAGEMENT IN 156 PATIENTS OPERATED UPON FOR MITRAL INSUFFICIENCY

	NO. OF CASES	DIED	MORTALITY (%)
I. Transventricular pericardial hammock	52	20	38.5
II. Transventricular suturing of the valve	72	20	20.8
III. Modern valvular suturing	25	4	16
IV. Transvalvular posterior pericardial diaphragm	7	0	0
Total	156	44	28.2

SUMMARY

1. Mitral insufficiency in well-developed form is one of the two most devastating acquired valve lesions.

2. A functional and a pathologic classification of this condition has been presented.

3. An anatomical and pathologic explanation of the two commonest types of mitral insufficiency is given. The characteristic tendency toward posterior localization of the incompetence is pointed out and a suggested explanation has been advanced.

4. The ultimate fate of pericardial tissue inserted into the heart is shown.

5. The various types of valvular suturing and their basic underlying principles of action are detailed.

6. The concept and application of a pedicled transvalvular pericardial diaphragm is described.

7. The use of the "mitral stitcher" for valvular suturing by the transatrial approach and the use of the Gemeinhardt pump in supporting and maintaining the circulation in unstable cases are indicated and the technique of their use is described.

8. The results of these corrective attempts to date have been summarized.

CONCLUSIONS

We believe that mitral valvular repair by grafting free or pedicled pericardial tissue within the valve orifice is a completely sound and logical method of permanently relieving mitral insufficiency in most clinical cases.

In certain patients suspension of one leaflet by an artificially created "papillary support" of pericardial tissue is extremely valuable.

With the evolution of these methods and increased understanding of the problems, the operative mortality and the clinical results obtained will soon become comparable in mitral insufficiency to those achieved with other forms of mitral valve surgery.

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(For Discussion see page [illegible])

THE SURGICAL CORRECTION OF MITRAL INSUFFICIENCY

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INTRODUCTION

IMPROVED techniques for the correction of mitral stenosis by valvuloplasty have brought the problem of mitral insufficiency into sharper focus. If a reasonable surgical treatment for this lesion can be offered, the whole field of mitral valve surgery will be improved in three ways. Those suffering from pure mitral incompetence can be treated. Those who might have either stenosis or insufficiency, now being denied surgery because of this question, can be operated upon definitively. Finally, those individuals thought to have mitral stenosis who at operation prove to have free insufficiency can be treated rather than abandoned.

During the past six years, in the course of treating more than one thousand patients with diseased mitral valves, there has been a unique opportunity to gain firsthand information about the nature of mitral incompetence clinically, pathologically, and through observation and palpation at the operating table. While not within the province of this presentation, the life cycle of mitral insufficiency has become clarified, the diagnosis and recognition have been improved, and therefore the indications for surgical intervention are better defined.[1, 2] Simultaneously, a better understanding of the morphologic pathology has been translated into a working concept of *kinetic pathology*, i.e., the total effect on hemodynamics in the living state of the diseased leaflets, myocardium, annulus, chordae tendineae, and papillary muscles.

The purpose of this communication is first to outline the patterns of morphologic pathology and to describe the kinetic pathology of this lesion as observed in the living human being. With this foundation an appreciation of the cardinal importance of the preservation of leaflet mobility becomes apparent. The fundamental attributes of pure mitral insufficiency are clari

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fied. It will be shown that in pure or mixed mitral insufficiency one or a combination of conditions must exist: (a) the leaflets may be too short, (b) the annulus may be too large, (c) the leaflet moorings may be defective, or (d) leaflet margins may be of such texture or configuration that they close incompletely. It will be demonstrated that the problem in pure mitral insufficiency is that of the *absolute* or *relative loss of leaflet substance*. To correct this loss of substance there must be either a substitution of substance or reduction of the size of the annulus. Various techniques that have been advanced to accomplish these ends will be reviewed. Evidence is presented in support of the use of a smooth Lucite baffle or prosthesis so placed in the mitral orifice as to obstruct the regurgitant jet in systole without interfering with leaflet mobility and the forward blood flow in diastole.

The operation to be presented represents one that has been evolved in the laboratory and applied to human beings. The first baffle was spherical in shape, the ball baffle. The second was more effective as it was bottle-shaped and was placed across the orifice with the base anchored to the anterolateral aspect of the annulus with the neck of the bottle riding under the opposite portion of the annulus. A number of problems presented by this prosthesis will be discussed. The spindle shaped baffle anchored at both ends across the orifice is apparently the most stable and efficient. The rationale and technique of this operation are presented for consideration in the light of the early clinical results on seventeen patients.

MORPHOLOGIC PATHOLOGY

In mitral valvular disease a whole spectrum of pathologic states ranging from pure stenosis to pure insufficiency exists. Very little is known about the pathogenesis of these lesions but it would appear reasonable to assume that stenosis occurs when in the bullous phase of acute rheumatic valvulitis the edges of the leaflets are forced together and adhere. This fusion probably progresses from the periphery where the range of motion is least and gravitates centrally until significant obstruction occurs. It is also conceivable that broad zones of swollen leaflets pressed into apposition can seal together as a relatively acute process. Such a sequence of events would result in mitral stenosis.

It is not difficult to conceive of a less intense inflammatory reaction or even a different type of reaction resulting in scarring, shortening and contracture of leaflets and chordae tendineae without causing them to adhere. This would produce an incompetent valve. In our experience the end result of such a pathologic process can be classified in five general patterns.

Type I. Absolute Loss of Substance.—This is the basic form mentioned previously wherein the rheumatic process has attacked the leaflets directly and the resulting contracture prevents them from closing in systole (Fig. 1 *A*). Because of its important function in the left ventricular outflow tract damage of the aortic leaflet results in the most serious incompetence.

Type II Relative Loss of Substance.—This occurs either as the result of rheumatic carditis which attacks the annulus directly or because of generalized left ventricular dilatation secondary to myocardial disease and failure. As the annulus enlarges the valve leaflets otherwise adequate in length fail to approximate and regurgitation results. This mechanism includes those forms of incompetence often referred to as "functional insufficiency" (Fig. 1 *II*).

In our experience almost all *pure mitral insufficiency* results from a combination of the afore-mentioned two mechanisms. Conspicuous features of pure insufficiency are the absence of calcification and the resultant free mobility of the leaflets. With mitral incompetence resulting from absolute loss of leaflet substance left ventricular chamber dilatation must occur to compensate for the volume regurgitated with each systole if cardiac output is to be maintained. This in turn produces enlargement of the valve ring with relative loss of substance augmenting the regurgitation. Thus the peculiarly self aggravating nature of this disease becomes apparent.

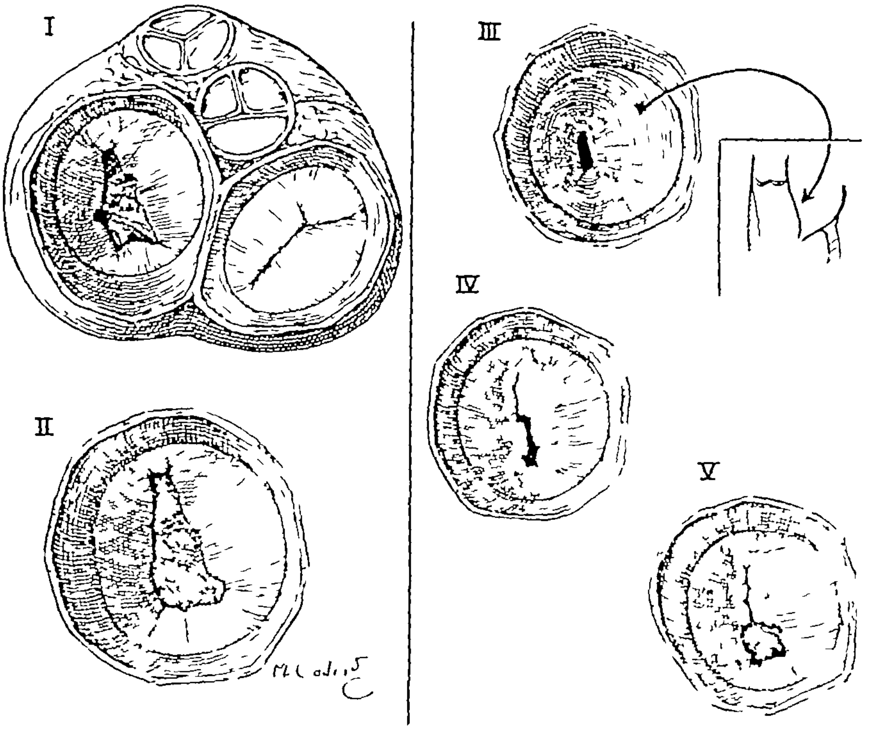


Fig. 1.—The five basic morphologic types of incompetent mitral valves. *I*, absolute loss of substance; *II*, relative loss of substance; *III*, directional; *IV*, malocclusion; *V*, mixed pathology.

In addition to these "pure forms" of mitral regurgitation, there are three other forms in which the predominant problem is usually stenosis. In general our policy has been to treat only the stenosis. Since there is some incompetence of the mitral closing mechanism however these pathologic processes must be included in a morphologic classification of mitral insufficiency

Type III Directional—This form of mitral insufficiency occurs when a stenotic mitral orifice faces into the left ventricular outflow tract (Fig 1 *III*) The nature of the abnormally rigid stenotic orifice prevents closure and its position precludes obstruction by the ventricular wall in systole This type of valve has been described previously as Group B mitral stenosis[3, 4]

Type IV Malocclusion—The regurgitation in this instance results from the inability of irregularly calcified leaflet margins to seat properly when the valve closes (Fig 1 *IV*) The result is a ribbon shaped jet Again since mitral stenosis is the predominant lesion in most of these cases correction aims only at relief of the obstruction

Type V Combined Pathology—Finally, a significant number of cases have been encountered in which fusion of leaflet margins and heavy calcification (the pathology common in pure mitral stenosis) will be found at the anterior commissure while posteromedially there is loss of leaflet substance without calcification resulting in a significant area of insufficiency (Fig 1 V)

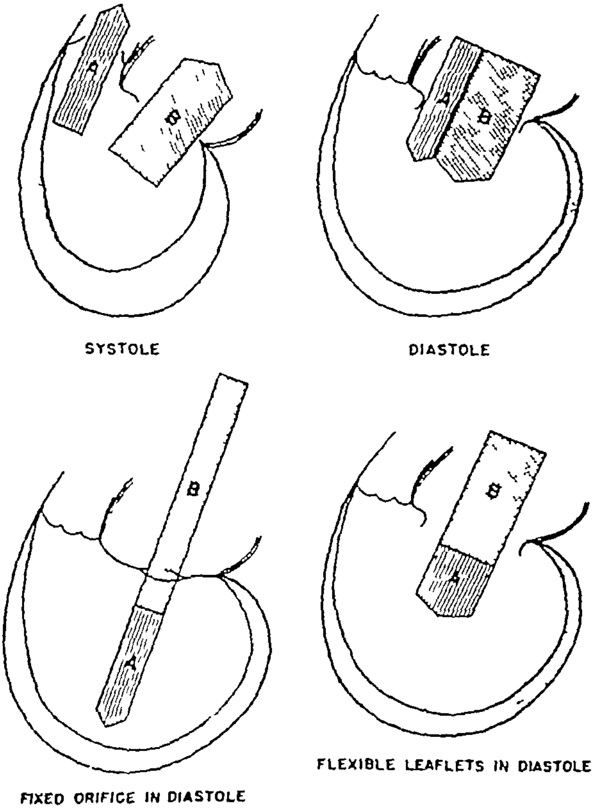
The quantitation of stenosis and insufficiency in such instances and thus the management of such a lesion presents a difficult problem We have had numerous brilliant clinical results following the correction of stenosis alone when this type was found even though there is substantial associated incompetence When the degree of stenosis is negligible however treatment must be directed at the dominant insufficiency A discussion of how to determine whether stenosis or regurgitation is dominant in such a situation properly falls within the province of kinetic pathology or hemodynamics but in order to emphasize the correlation of the morbid pattern with the dynamic valve function it may be said that the identification of the significant lesion can often be made at the operating table This is done by using the intra-auricular finger as a baffle or substitute for the lost leaflet substance the regurgitant jet can thus be obstructed without interfering with leaflet mobility Ventricular filling proceeds normally as the leaflets fall away from the finger but the leaflets plus the finger prevent regurgitation in systole If the leak is significant the blood pressure will rise from 20 to 30 mm Hg within a few beats

KINETIC PATHOLOGY OR HEMODYNAMICS OF MITRAL INSUFFICIENCY

There are at least three features that should be reviewed

1 The first of these involves the pressure relationships between the left auricle the left ventricle and the aorta It is at once apparent that the gradient in *systole* between the left ventricle and the left auricle is much greater than the gradient between the left ventricle and aorta Thus if the orifices were of similar size the incompetent mitral opening would allow much more blood to regurgitate through it than would be ejected into the aorta as effective cardiac output Nevertheless in the face of this disadvantageous pressure relationship[7] during loss of effective systolic ejection from the left ventricle a quantity of blood equal to the combined aortic output and the

regurgitant jet must flow from the auricle into the *ventricle in each* diastolic period. That is, auriculoventricular flow in diastole must equal the combined volume of blood put out into the aorta and back into the auricle during each contraction (Fig. 2 upper *pair*). *In* addition there is another deterrent to maintaining adequate ventricular filling in diastole. The forward flow in diastole is at a low pressure gradient and therefore at a low *velocity* whereas the reflux in systole is at a high gradient and velocity. There are two principal mechanisms of compensating for this unfavorable dynamic situation. One is that the slower flow from auricle to ventricle may exist over a longer period of time, i.e. *diastole may be prolonged*. The limitations of bradycardia are apparent although a given degree of incompetence will obviously be better tolerated with a slow rate. The principal mechanism by which circulation is maintained is therefore through change in the size of the mitral orifice so that the large volume of blood traveling at a low velocity in diastole proceeds through a larger orifice than the regurgitant jet in systole. This depends on



SYSTOLE DIASTOLE

FIXED ORIFICE IN DIASTOLE FLEXIBLE LEAFLETS IN DIASTOLE

Fig. 2.—(Upper pair) The combined volume of *A* and *B* must flow into the ventricle during each diastolic period. The pressure gradients are *unfavorable to the forward flow* as opposed to the rapid systolic reflux.

(Lower pair) The two principal compensating factors for this larger volume of forward flow at a lower velocity are prolongation of diastole and increase in the size of the mitral orifice (largely through leaflet mobility).

the maintenance of leaflet mobility (Fig 2 lower part) The partial occlusion of the orifice by the ventricle or by annulus contractility are probably additional minor factors The cornerstone of our efforts at surgical correction of this lesion has been this important preservation of leaflet mobility so that the orifice can be larger in diastole and can become smaller in systole

2 The second important concept of the kinetic pathology of this condition is that *mitral regurgitation is a peculiarly self-aggravating disease* When a significant amount of regurgitation occurs a certain percentage of the left ventricular stroke volume is dissipated in retrograde flow In order to maintain an adequate cardiac output the left ventricle must dilate to accept a compensating volume of blood This leads to an increase in the size of the annulus which in turn increases the *relative insufficiency* of the leaflets More regurgitation leads to more dilatation and a vicious cycle is established Thus the self aggravating nature of this condition is defined Conversely, any reduction of reflux reduces ventricular volume and as the mitral annulus shrinks simultaneously the leaflets more nearly approximate Effective partial correction of this lesion should therefore be *self-perpetuating,* provided that the ventricular myocardium has not exceeded the limits of its recuperative powers Failure to make adequate allowance for this dynamic change may result in the creation of stenosis by a *procedure* which attempts to correct the leak totally at the time of operation Our experience in this regard will be described

3 The third cardinal concept has already been mentioned When the surgeon encounters free or significant mitral insufficiency on exploring the mitral valve it is possible to hold the finger in the regurgitant jet at the leaflet level in such a way that the leaflets slap firmly against it and a more competent valve results This is uniformly associated with a prompt elevation of the blood pressure by as much as 30 mm Hg Although instantaneous cardiac output determinations are not available this prompt blood pressure elevation must correlate with an elevated cardiac output The reduction of the regurgitation must also reduce the left ventricular work It is felt that these salutary changes can be simulated on a permanent basis by the surgical [illegible]

SURGICAL CORRECTION

Considerable ingenuity has been demonstrated in devising surgical procedures for the correction of mitral insufficiency Murray Wilkinson and McKenzie [illegible] experimentally and then in man to resect a portion [illegible] After turning [illegible] segment [illegible] pulled strip of tendon through its lumen [illegible]

Bailey and his colleagues[6] repeated this operation in animals and human beings suffering from mitral regurgitation employing a sling made from a pericardial pedicle graft. Adequate experimental and clinical trial has now established the fact that these "slings" do not survive but shrink to atrophic fibrous bands. Among those who have had similar experiences are Glover and his associates[7] and Moore and Shumacker.[8]

Certain objections have existed which have led us to doubt the validity of this approach. First, the slings do not survive, as already mentioned. Second, whether they lived or atrophied, they offered a framework for thrombus formation with the threat of embolization or overt obstruction. Third, even though the sling continued to function as planned, there existed the strong probability that it would become jammed into the orifice with the force of ventricular systole in such a way that the much feebler force of diastolic flow could not dislodge it. Finally, an understanding of the kinetic pathology outlined previously indicated that if a sling of the proper length to correct a given state of insufficiency in a ventricle and annulus of one size did in fact correct that regurgitation, the size of the ventricle and annulus would diminish so as to render the sling no longer suitable. (This particular pitfall in our own work will be presented.) For these and other reasons, the procedure has been abandoned even by its early proponents.

Years ago when the valvuloplastic techniques for mitral stenosis were undergoing development, it seemed possible that mobilization of the leaflets might improve the hemodynamics of insufficiency. The limited place for such an approach is apparent from the discussion previously of the morbid pathology of regurgitation. Similarly, the limited application of "unrolling leaflets and stretching chordae" as described by Dodrill[9] is apparent. We have shared the optimism and frustration of others in pursuance of these proposals.

Recently Davila, Mattson, O'Neill, and Glover[10] have described an ingenious experimental technique of reducing the size of the annulus. Previously we have repeatedly observed that pressure on the posterolateral aspect of the left ventricle can distort the annulus of an incompetent mitral valve into an elongated elipse so that the absolutely or relatively inadequate leaflets are rendered competent. This observation prompted us on three occasions to place a distorting suture obliquely across the annulus from the posteromedial to the anterolateral aspect; the ends were anchored externally on nylon buttons. One of the patients succumbed soon after operation, and it was found that the degree of distortion possible had been quite insignificant due to sheer muscle mass of the hypertrophied myocardium (Fig. 3). A second patient survived, and there was evidence both at operation and subsequently of improved hemodynamics and reduced regurgitation. Unfortunately, she had a fatal cerebral embolus six weeks later. A third patient has been followed for more than a year. In this instance the palpable regurgitation was completely obliterated by the annulus distortion at the time of operation, but a systolic murmur and presumably some regurgitation have persisted. While the patient may be regarded as improved, the operation has not constituted definitive therapy. Because of the difficulty in significantly altering markedly hypertrophied ventricles, because of the inherent danger of embolus associated with open transorificial sutures and because of the possible variation in size in different phases of the cardiac cycle, this technique has now been abandoned.

On reviewing the aforementioned experimental and clinical work, it would appear that the use of living tissue is unsatisfactory. At the same time we have been reluctant to adopt nonliving prosthetic valves with moving parts for fear they would wear out or stick. The paradox then presents itself of being unable to accept living tissue and nonliving substance with moving parts. A compromise in this dilemma appears to exist in a nonmoving nonviable prosthesis that may be moved by or with the adjacent myocardium and at the same time preserve the vital mobility of the leaflets.

Fig. 3.—Autopsy specimen. Hypertrophy of the myocardium rendered distortion of the annulus difficult. The incompetence was not corrected by the transorificial suture. Note external buttons anchoring ends of suture.

THE EVOLUTION OF THE SPINDLE BAFFLE OPERATION

Our first attempt to employ a prosthesis to supplement valve substance in mitral insufficiency was with the Lucite ball baffle procedure. The plan was to mount the ball on the ventricular myocardium just beneath the ventricular leaflet. This ball was not to move on its moorings but was *to be moved* by the myocardium into the deficient mitral orifice during systole and to fall away from the opening in diastole (Fig. 4). The Lucite sphere was introduced through the auricular appendage and drawn into position by sutures that had been inserted through the ventricular myocardium. The maneuvers were essentially similar to those used and illustrated here in connection with the spindle-baffle operation. The results of this operation were discouraging. The eight patients on whom it was performed died in from one day to nine months after surgery. It was apparent that the terminal course in these dying patients had not been interrupted. Examination of the prostheses at autopsy confirmed the laboratory evidence that they were well-tolerated and did not erode the myocardium. Analysis of these human cases, however, revealed a fallacy in our concept of the shape of the left ventricle in mitral insufficiency. We had failed to take into consideration the enormous dilatation of this chamber that was present. Consequently, when the ball was placed on the myocardium beneath the ventricular leaflet, it, in fact, came to lie lateral to the valve orifice and not near the orifice where the motion of the myocardium could bring about the desired occlusive effect in systole. The ball simply had no effect on the orifice in life even though in the atonic state at autopsy the position seemed satisfactory (Fig. 5).

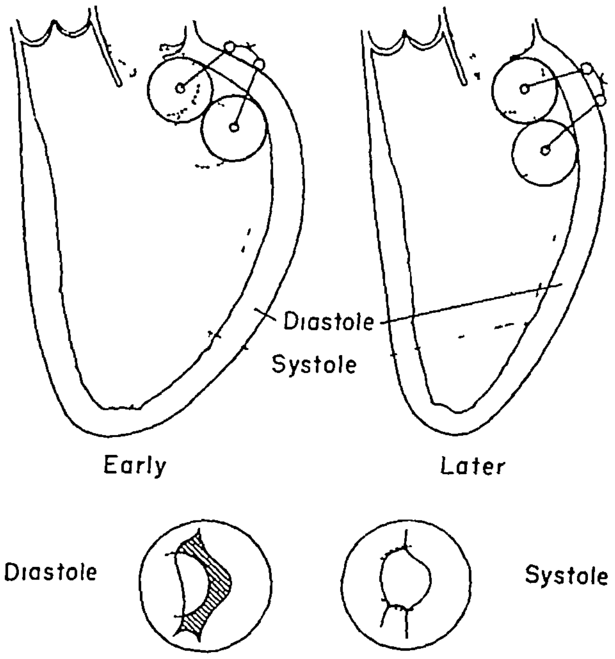


Fig. 4.—This theoretical action of the ball baffle was not accomplished because of the abnormal contour of the dilated ventricle in mitral insufficiency.

The failure of the ball-baffle led to an alteration in its shape so that it could traverse the incompetent orifice effectively. A Lucite prosthesis in the shape of a bottle was anchored above and below the anterolateral aspect of the annulus and its neck engaged either under the midportion of the aortic leaflet or under the posteromedial fringe of leaflet insertion on the annulus. By placing the baffle properly in the mitral defect the same elevation of systolic blood pressure brought about with the finger could be duplicated

(Fig. 6). Twenty-four terminal patients with pure mitral insufficiency were operated on using this procedure. There were seven postoperative and seven late deaths. An analysis of these deaths in terms of principal cause is relatively simple but in actual fact, except for four technical difficulties incident to the insertion of the prosthesis, the terminal event was generally a combination of more than one factor. In three patients the prosthesis that seemed appropriate in size to correct the defect encountered at operation did eventually overcorrect the insufficiency when the chamber contracted and reduced the annulus in size. The reversal of the "self-aggravating cycle" described earlier was effected with fatal consequence. Five patients succumbed from emboli apparently propagated from exposed suture material. There was one embolus of the prosthesis itself. This bottle had been inadequately anchored due to technical problems at operation. It represents the only such tragedy in the series. Three of the patients who succumbed from emboli and two

Fig. [illegible]—Autopsy specimen. Ball baffle appears to lie in effective position beneath ventricular leaflet on left [illegible] of illustrations. Note Type I and Type II pathology. Tricuspid valve [illegible] at right.

others who have succumbed had persistence of irreversible congestive failure. Of the ten surviving patients there has been substantial improvement in eight, even with rehabilitation to a normal level of activity from a preoperative status of invalidism.

The inconstancy of improvement from patient to patient with the bottle shaped prosthesis was felt to be correlated with inconstancy of the position maintained by the baffle. Technical difficulties of baffle insertion attended the initial efforts. Exposed sutures were associated with lethal emboli. Overcorrection or regurgitation with resultant stenosis also made any benefit from the operation difficult to discern. Finally, the patients themselves were in many instances accepted so frequently late in their disintegrating phase that even a perfect mechanical valve might go unrecognized in the face of malignant *myocardial* pulmonary, and liver changes (Fig. 15). However, the incontrovertible improvement of some of the patients confirmed the correctness of the principles involved.

The apparent virtues of the method demanded that: (1) the technique of insertion be made simple and readily reproducible, (2) the baffle be inserted in an effective position with both ends anchored so that the variations in clinical results attending alteration of the baffle position do not occur, (3) that exposed suture material be eliminated if propagation of clot and therefore embolization are to be avoided, and (4) a baffle of just sufficient size to initiate the self-perpetuating return to mitral competence must be inserted so that mitral stenosis does not occur.

The first or *technical* difficulty seems to have been overcome in the so called spindle-baffle procedure illustrated here. The operation has been carried out *seventeen times with three surgical deaths and one late death. None of the* deaths were due to technical problems at operation.

The second problem, that of *anchoring both ends of the baffle* so that the defect inherent in the bottle procedure—the possibility of the unanchored end becoming dislodged—has been solved. The anterior and narrower end is anchored under the leaflets and annulus within the chamber of the ventricle whereas the larger end of the teardrop shaped spindle is firmly fixed above the annulus posteriorly. Thus, while substituting for the loss of substance and allowing the continuation of full leaflet mobility the baffle cannot migrate out of position (Figs. 7 and 14).

The third problem of *embolization* or propagation of thrombus from exposed sutures has apparently been controlled. There have been none thus far. This improvement is almost certainly related to the fact that the technique illustrated allows firm *anchoring* with minimal exposed suture material. The patients have been placed on Heparin immediately after surgery for five days, then shifted to Dicumarol for five weeks.

The fourth pitfall—that of inserting too large a baffle and eventually *overcorrecting to mitral stenosis—has not occurred since the spindle baffle has* been used. Recognition of the potential problem is the best prophylaxis in this situation.

THE TECHNIQUE OF THE SPINDLE-BAFFLE OPERATION FOR THE CORRECTION OF MITRAL INSUFFICIENCY

The patient is anesthetized with *Pentothal and an endotracheal* tube is inserted. Minimal amounts of ether *maintain anesthesia.* The respiratory assistor[11, 12] is used *routinely, thus ensuring maximal oxygenation* and carbon dioxide clearance.

With the patient in the right lateral decubitus position *the appropriate* skin preparation and draping are followed by an incision over the entire left sixth intercostal space. The interspace is opened and the sixth *rib is divided* at the transverse process posteriorly and through the cartilage at the sternum

If necessary the fifth costal cartilage is also divided. With the ribs spread the classical cardiac and pericardial silhouette presents. The pulmonary artery is generally small and hypotensive. The left auricle is often tremendous. The pericardium is opened posterior to the left phrenic nerve from above the pulmonary artery to the diaphragm in a line directed somewhat

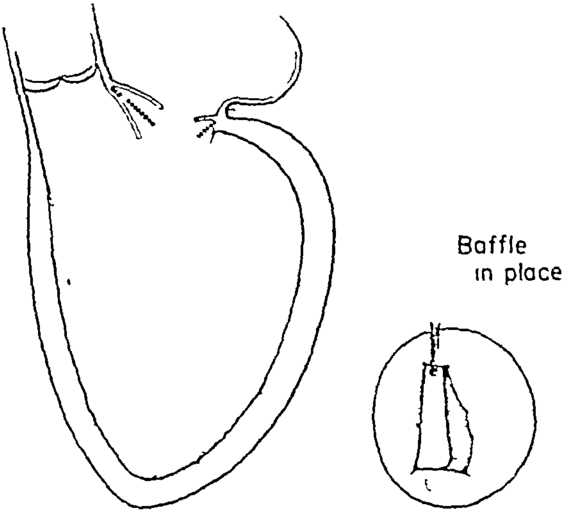


FIG. 6.—The bottle-baffle lies in a more favorable position for obstruction of the regurgitant jet and preserved leaflet mobility. Note bulging left ventricular myocardium and change in baffle size if leaflets are flexible.

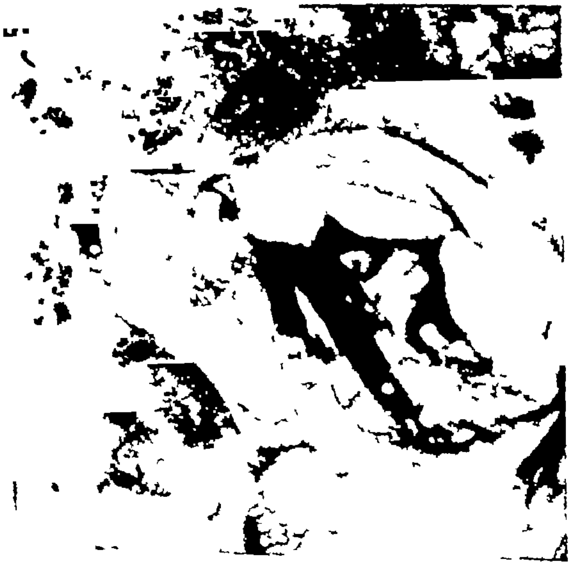


FIG. 7.—Autopsy specimen. The [illegible] ball [illegible] is placed [illegible] through the incompetent [illegible] firmly [illegible] and [illegible] The [illegible] the annulus.

dorsally. Retraction of the incised margins of the pericardium affords excellent exposure of the left auricular appendage, the lateral aspect of the left ventricle, and the phrenic surface of the left and right ventricles.

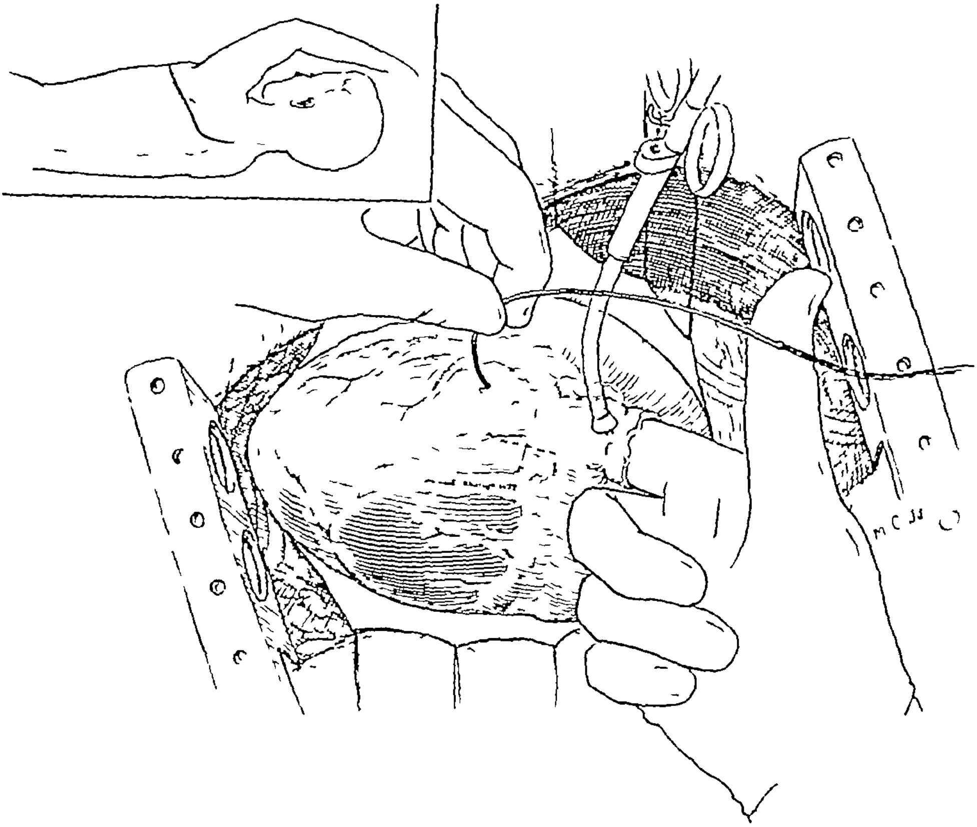


Fig. 8.—Technique of the spindle baffle operation. Placing the anterior mooring of the baffle below the anterolateral margin of the annulus.

Purse-string sutures are then placed about the auricular appendage, the Rumel tourniquet is attached to one of these sutures, and the tip of the appendage is amputated with an auricle clamp controlling blood loss. The finger is then inserted into the auricle and the nature of the mitral incompetence explored. The finger is placed over the regurgitant jet in various positions and the patient's blood pressure is checked. The most effective position of the "finger baffle" is that which produces the greatest rise in the systolic pressure as reported by the anesthesiologist.

The next step is to place a spindle baffle of appropriate size and shape to simulate the salutary effect of the finger-baffle. As the surgeon palpates the orifice with the distal phalanx of his right index finger, he can compare various sizes and shapes of baffles with the corresponding phalanx of his left index finger, thus making a reasonable selection of an appropriate prosthesis.

Almost invariably the greatest leak occurs posteromedially. The narrow end of the spindle is therefore placed anteriorly just beneath the annulus against the ventricular myocardium and the broader extremity is brought up

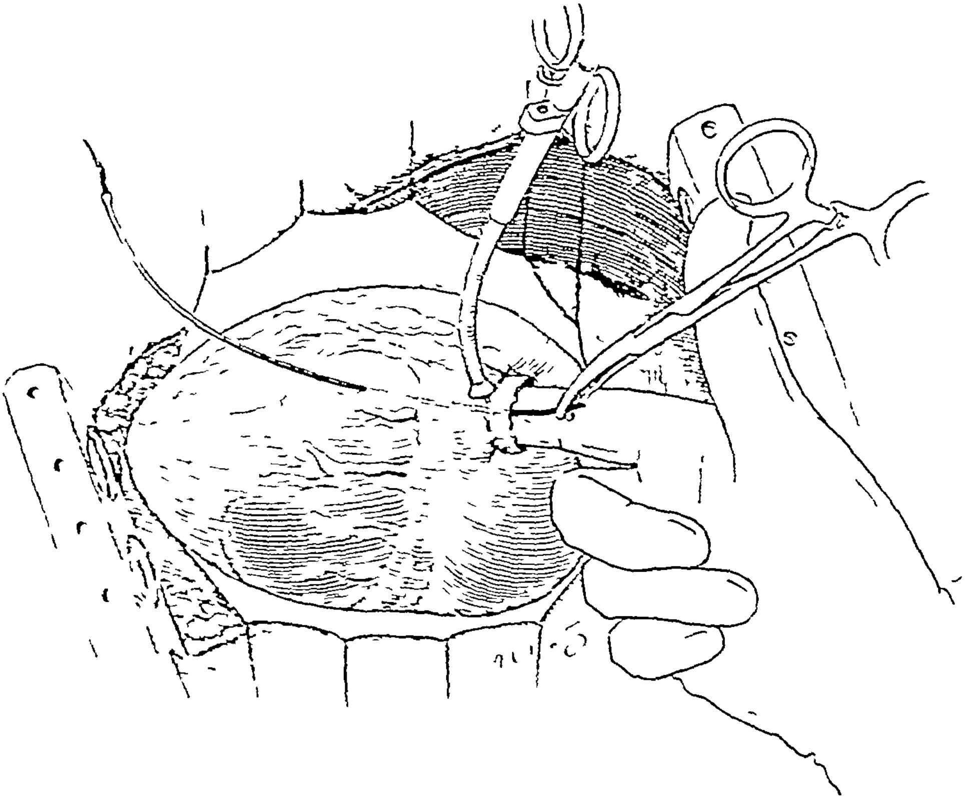


Fig [illegible]—Technique of the [illegible] baffle operation. Recovering the malleable needle from the auricular lumen.

through the orifice and fixed posteromedially just above the annulus. Thus the prosthesis comes to lie obliquely through the mitral valve. It presents a smooth nonreactive polished Lucite surface to the leaflets as they close in systole and because it does not interfere with their mobility allows unhampered opening in diastole. The oblique position traversing the orifice ensures supplementation of leaflet deficiency regardless of changes in size of the annulus and of the ventricle (Fig 14).

The placing of the baffle is achieved as follows. A 12 cm malleable needle with three strands of braided No 1 nylon suture swedged on its end is threaded through the myocardium so that it enters the chamber of the left ventricle near the anterior commissure (Fig 8). The point of entry is in an avascular area between the anterior descending and the circumflex branches of the left coronary artery. It is then threaded up through the mitral orifice [illegible] appearing on the guiding finger is illustrated (Fig 9). The needle is passed through the appropriate spindle-baffle. It is then reinserted into the left auricle using the finger as a guide and directed so as to pierce the auricular surface of the posterior segment of the mitral annulus (Fig. 10). The needle is finally pushed through the ventricular myocardium beneath the coronary sinus and circumflex coronary artery, to exit from the heart just medial or just lateral to the posterior descending coronary artery on the phrenic aspect of the left ventricle. Thus, having in effect traversed the heart, the posterior end of the three nylon sutures is tied to a nylon button 1.5 cm. in diameter. By traction on the loop which is still emerging from the left auricular appendage the posterior button can be pulled firmly against the posterior wall of the left ventricle where it acts as the anchor for the broad posterior end of the spindle. Traction is next applied on the three nylon sutures as they issue from the anterior wall of the left ventricle drawing the spindle to the auricular appendage (Fig. 11). Further traction properly timed with triangulation of the open end of the appendage and brief removal of the finger makes it possible to "bob" the spindle into the heart without significant blood loss. As the anterior button is slipped along the three mooring sutures a completely stable position under any desired degree of tension can be attained (Fig. 12).

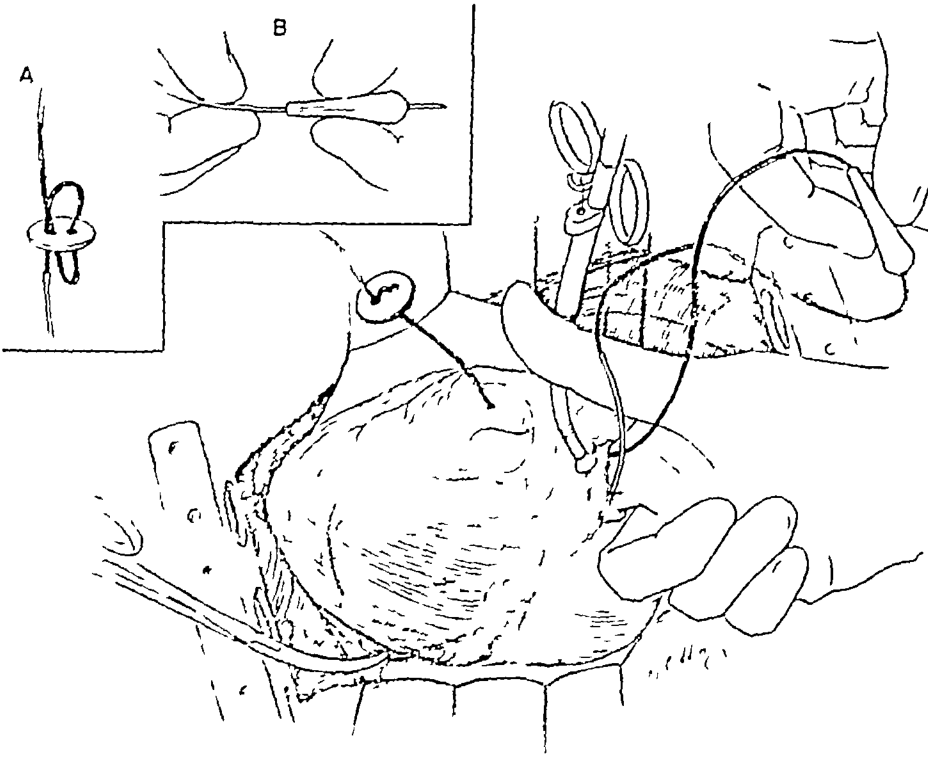


Fig. 10.—Technique of the spindle-baffle operation. The needle is threaded through the spindle from narrow to wide end. It is then reinserted into the auricle and through the auricular aspect of the posteromedial segment of the annulus.

On numerous occasions the blood pressure has risen 30 to 50 mm Hg immediately after placing the prosthesis just as had occurred when the jet was obstructed with the finger This observation would seem to substantiate the palpatory evidence of significant diminution in the volume of the regurgitant jet and indicate a salutary effect on the cardiovascular dynamics The finger is then withdrawn from the appendage as the purse-string sutures are tied Finally the auricular margins are oversewn (Fig 13) and the pericardium is loosely closed with a pad of Gelfoam over each button

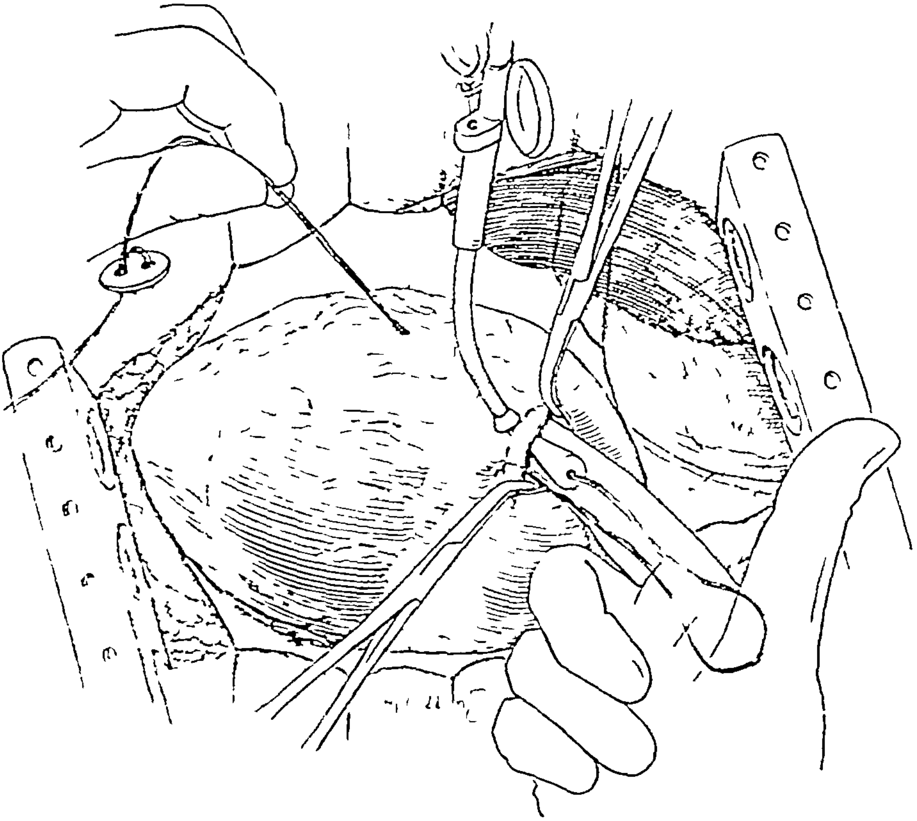


Fig 11—Technique of the spindle baffle operation Traction on the anterior (following [illegible] suture pulls the posterior button into place and draws the [illegible]

RESULTS

Among the seventeen patients who have had the spindle baffle operation there were three operative deaths.[9] The first loss was in a terminal patient who had been bedridden and unable to be brought into even a transient state of compensation. Plugging the leak with the finger resulted in no improvement

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[illegible]

in the circulatory state at operation and the blood pressure failed to rise. Presumably, the myocardium had failed irreversibly. Nevertheless the prosthesis was placed simply as a last resort at this point. The patient awakened and responded following surgery but quietly expired within one-half hour with a progressively failing myocardium.

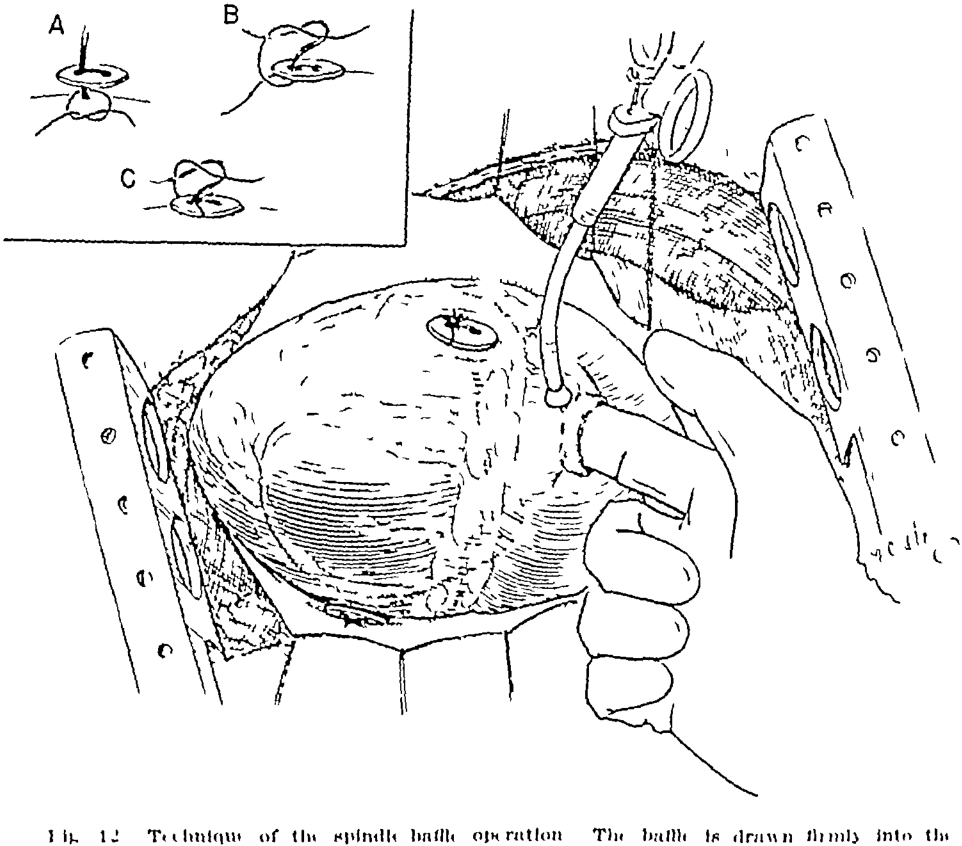


Fig. 12.—Technique of the spindle baffle operation. The baffle is drawn firmly into the oblique position by traction on the sutures. The position is fixed by sliding the button down the sutures and securing it at the desired tension.

The second failure followed a technically simple operation, and the patient made the uneventful postoperative response similar to that we have come to expect after the valvuloplastic correction of mitral stenosis. However, after eating a hearty breakfast on the morning of the fifth postoperative day and making a phone call to her husband she suddenly turned her head, gasped and expired within a few seconds. Autopsy revealed nothing more than a baffle in a completely satisfactory position (Fig. 7). The death is presumed to have been due to an acute arrhythmia similar to the Stokes-Adams attacks she had experienced preoperatively.

The third surgical death resulted from inadvertent dislodgment of a large clot from the auricle in a patient who had had a large femoral embolus re-

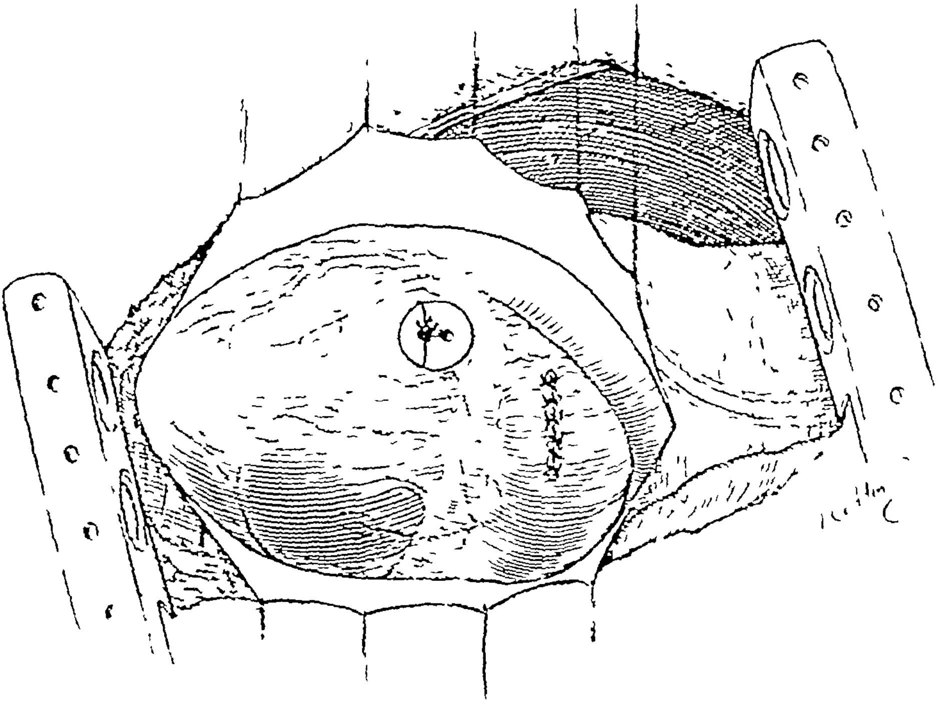
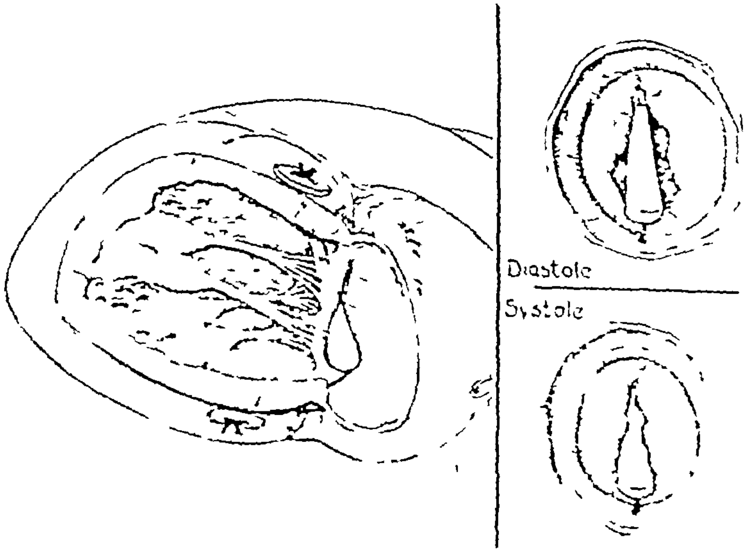


Fig. 1[illegible].—Technique of the spindle baffle operation. The appendage is closed by tying the purse string sutures and oversewing the margins of the auricle.



[illegible]

moved a few days before. This patient probably should not have been offered this procedure for the reason mentioned, and also because she had aortic stenosis and insufficiency. The one *late* death occurred in a man who was brought into partial compensation by prolonged medical treatment including one month in the hospital prior to surgery. The spindle-baffle further improved this compensation but one month after discharge irreversible congestive failure reappeared and led to his death.

Fig. 15.—Roentgenogram of a patient in the spindle baffle series. The left auricle comprises the bulk of the cardiac shadow extending to the left and right. Left ventricular enlargement is apparent in oblique views. Lung fields are relatively clear.

The surviving patients have had incomparably smoother postoperative courses than those patients who have had other types of surgery for the correction of mitral insufficiency. Furthermore observation of the patients since discharge from the hospital is encouraging.

A conservative note must be sounded with respect to final evaluation of this procedure because we have been disappointed before and the problem of mitral insufficiency is a much more complex one than that of mitral stenosis. The left ventricular myocardial component at least in these terminal patients represents a factor that makes the favorable response less dramatic, the result less immediate and less complete, and perhaps even renders good valve surgery less obvious. Certainly if this procedure can help these terminal patients and is associated with few or no late complications it will afford more dramatic results when patients are accepted who do not have the crippling secondary changes (Fig 15)

In the first year of our experience with the Lucite spindle-baffle operation for the correction of mitral insufficiency it would appear that an operation reasonable in principle simple of application and salutary in effect is available The operation probably can be performed with a low surgical mortality comparable to valvuloplasty in the various stages of clinical illness

The complexity of the clinical and pathologic problem however dictates that those patients whose clinical status is stable and who can safely await further evaluation of this procedure should do so On the other hand patients who have pure mitral insufficiency and whose condition is deteriorating on a good medical regime can conscientiously be offered this procedure

SUMMARY

1 A morphologic classification of the pathology of mitral insufficiency is presented

2 Some cardinal features of the kinetic pathology are described

3 Various techniques that have been tried in other clinics to correct mitral insufficiency are reviewed

4 Some of the problems incident to the surgical correction of mitral insufficiency are defined

5 Various unsuccessful techniques in our experience are mentioned

6 The rationale technique and results of the ball-baffle bottle baffle and spindle baffle operations are presented

7 The spindle baffle operation is considered sufficiently promising to deserve continued trial under restricted conditions in the human being

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DISCUSSION

(PAPERS BY BAILEY, JAMISON, BAKST BOLTON, NICHOLS, AND GEMEINHARDT AND HARKEN, BLACK, ELLIS, AND DEXTER)

DR CHARLES B RIPSTEIN, Brooklyn, N Y—The problem of mitral insufficiency is one with which Dr Bailey, Dr Harken, and many others have wrestled for a long time and, although it seems we are a bit nearer to a solution, there is still a long way to go In analyzing the pathology in a good many cases we have seen at autopsy, certain facts have become quite striking to us

In many cases the pathology seems to be a pulling down or adhesion of the mural leaflet in the posterolateral corner and with a flexible knife this can often be freed and divided and pulled up into place in which the way Dr Dodrill described about a year ago We have found that this really does work and it is quite often possible to convert what appears to be an absolute lack of valve substance into a relative lack

This is not always enough, because in addition to the shortening of the chordae and the adhesion of the mural leaflet the A V ring is dilated and usually the posterior leaflet will not stay in position

We have tried to hold it up by passing the suture under the leaflet in much the same way that Dr Bailey s sling accidentally got there but doing it with tendon, as Gordon Murray and others showed some time ago Tendon grafts seem to be well tolerated in the heart and do not fibrose and shrink away We have taken palmaris longus tendon and used that to support the leaflet and to fill the gap in the posteromedial corner

In addition to that we have experimentally used a purse string suture to decrease the size of the annulus, but so far we have not had the courage to try this in the human being To date with freeing of the posterior leaflet supporting it with a tendon graft we have operated on 17 patients with mitral insufficiency some of whom have had concomitant stenosis There have been no deaths in this group and 14 patients are initially improved but obviously the follow up is still too short to be dogmatic about it This is just offered as another way of doing the same thing

DR FOREST B DODRILL Detroit, Mich—I should like to discuss primarily the type of deformity which I have encountered in seven consecutive patients in whom operation has been carried out for mitral regurgitation and to illustrate a type of procedure which I have attempted in these patients

The regurgitation is always at the posterior commissure In six of the seven patients it was the lateral posterior leaflet which was involved and approximately one half of the had marked contraction and shortening of the chordae tendineae which held the posterior aspect of the leaflet down into the ventricle and prevented its closing during cardiac systole The valve leaflet itself is not necessarily destroyed in other words if it is brought up into proper position so that it apposes the opposite leaflet the regurgitation is minimized or corrected In two of these patients the disease was definitely congenital since one was a year old child and the other a 7 year old child whom I had seen for a number of years Most of my patients did not give a history of rheumatic fever and it is questionable whether all of them may not be congenital in origin

The procedure which I carry out consists in inserting the finger into the atrium passing it down through the valve to palpate the chordae tendineae and papillary muscle If this is found to be short and preventing valve closure the finger is gently inserted under the valve leaflet and traction is made upward toward the atrium By so doing, one gradually and gently stretches out the chordae tendineae until the blood, during cardiac systole, gets behind the valve leaflet and further tends to push it upward toward its proper position That this mechanism actually occurs is borne out by the fact that in one of my patients the murmur was still present after operation but after the course of two months almost totally disappeared The first patient, upon whom I operated nearly two years ago, has been recently catheterized It is seen that his pulmonary capillary pressure is now 8 mm Hg or essentially normal whereas at the time of operation it was 30 mm Hg All patients have survived the procedure

The point I should like to make is this if there is sufficient valve leaflet for closure of the valve and if this valve tissue is simply distorted and pulled out of place it is better to try to use this tissue and to put it back in the proper place if this is possible

Mitral regurgitation is a severe disease and it is well known that a regurgitation of one sixth to one fifth of valve circumference decreases the cardiac output by at least 50 per cent so that any degree of improvement is a great benefit to the patient

DR T J O'NEILL Philadelphia Pa —At this point one thing should be quite clear that there are a variety of types of mitral valve regurgitation and that no one specific type of technique or procedure will apply to all these situations I should like to suggest one type of correction that has not been adequately explored at this time that is, the use of living tissue rather than prosthesis and suture techniques, some of which will not be available at time

Rather fortunately in some types of mitral regurgitation we find a large left atrial chamber and also a large left auricular appendage, and this tissue is available for use as grafting material One can completely invaginate, in certain of these individuals, the left auricular appendage down through the mitral valve orifice and wrap it around the deficient posterior leaflet This simulates Dr Harken's finger baffle maneuver it places a bit of tissue that can be made without any special techniques into a tube which is approximately as large as the finger and it can be anchored in a similar fashion as the prosthetic repair method through the annulus or below the coronary vessels

Dr Harken emphasized that the valve motility is important Usually the mitral aortic leaflet is the large mobile saillike leaflet and it has adequate motion as can be appreciated with the finger through the orifice and this will move back and forth away from the ball of tissue that is added to supply the deficient posterior leaflet so that on diastole it will open and the anterior leaflet will close against it in systole

I will demonstrate its appearance in dogs Here is the posterior leaflet destroyed and replaced by the inverted auricular appendage It is living tissue actually it has no [illegible] of living [illegible] only one or two sutures are placed through it This is the aortic leaflet It opens well It is the only mobile leaflet On systole it will close and wrap itself around that lower [illegible]

I realize that certainly not all patients have situations in the valve that will lend themselves to this type of correction but one does not have to worry much about what is going to happen to the ball of tissue that is left in the heart It is a part of the heart it is living there is no interference with its blood supply and it will not move if it is anchored properly We have operated on two patients with this technique without operative mortality [illegible] and the other unfortunately six weeks later lost the suture and [illegible] recurrence of the regurgitation tendineae and scar tissue by a small right angle neurectomy knife which has been introduced through the left ventricular wall, using the finger within the mitral valve as a guide

DR CHARLES P BAILEY, Philadelphia, Pa —As you know, Dr Harken and I *seldom see eye to eye on any new subject for several years, but eventually we do the* same thing, even if we call it by different names It is evident that we are becoming closer in our concepts and methods of management for mitral insufficiency

This is the slide which Dr Harken thought demonstrated a tricuspid valve I do not think it is a tricuspid valve and they did not think so at the Institute of Human Anatomy at Copenhagen, from which I obtained the specimen If Dr Harken considers every wrinkle in the mural leaflet as an additional commissure he must deem most valves multicuspid It took me six months to find a suitable human specimen of a mitral valve with an additional or commissural leaflet Here is a picture of it A quadricuspid valve is quite normal in the bull heart but Dr Jesse Edwards of the Mayo Clinic estimates it to occur only in about 5 per cent of human cases I do not know why Dr Harken has found so many hearts of the bull type in Boston, but we do not find them in Philadelphia

This slide is shown again to emphasize our old hammock or sling operation for mitral insufficiency and the spindle baffle operation of Dr Harken's Although it is true that he allows his spindle baffle actually to lie through the valve orifice, I can see that we are getting a lot closer together than we were

I do object to Dr Harken's repeated statements at medical meetings that our operation is designed to treat predominant stenosis and not regurgitation Fifty eight of our patients who were operated upon had no stenosis at all And unless one wishes to exclude from treatment all patients who have some stenosis, it is necessary to treat many individuals with some stenosis because about three fourths of patients with serious regurgitation present some narrowing of the valve orifice

I see that he has had experience with 51 patients Our operative experience has been with 150 patients, so I think we can recognize serious insufficiency and the results of surgical treatment at least as well as he can

I have clearly indicated our early and late mortality on the statistical slide Perhaps Dr Harken will tell us the same about the 18 patients operated on by his latest technique How many left the hospital alive, and how many are alive today ?

DR DWIGHT E HARKEN, Boston, Mass (Closing) —I shall have to send Dr Bailey *this manuscript I said specifically, of the eighteen patients, four died in the hospital* That would mean that 14 left the hospital *alive* One has died since, and unless someone has died since I was up here five minute ago, the others are living, and I might say doing quite well

I do not wish to prolong this foolish exchange, particularly with reference to the discussion of bicuspid, tetracuspid, and tricuspid leaflets, but when the previous speaker showed his slide a second time you may have noticed that there was quite a difference in the contour of the posterior commissural area and the anterior zone You must either conclude that there was one continuous horseshoe leaflet or, as I contend that there were two indentations posteriorly and, as is often the case, a separate set of chordae that clearly identify a posterior commissural leaflet This is seen when the ring is open, and it is a common arrangement Close scrutiny of specimens at the autopsy table will confirm this Dr Jesse Edwards has been quoted and I must say that except for a difference in percentages, we are in substantial agreement about the morphologic types The colored slide showed an anterior commissural leaflet Again, we are likely to see those things that we look for carefully, we cannot find those things which we do not know about This exchange has reached the point of diminishing returns

Dr Kipstein Dr Kay and Dr Dodrill have presented an interesting and challenging technique We shall give further attention to this maneuver We have not found suitable types at autopsy or in the operating room in the past Five years ago I performed five [illegible] by a similar technique and [illegible] to reach the chordae and leaflets. This was [illegible] successful. No doubt time will clarify [illegible] situation, and [illegible] will arrive at a compromise. Further experience may even find proper places for such divergent concepts as are represented by the suturing of leaflets and the use of the inert baffle. The diversity of [illegible] pathologic types that we recognize admits of a difference of opinion between con[illegible] [illegible].

Both left and right-sided cardiac catheterization, which is an objective measure of hemodynamic improvement of fundamental importance in these early operations, may be helpful. Similarly, pressure recordings across the mitral valve at the operating table may also be helpful. At this point our studies are inadequate. We can only say that the [illegible] pressure [illegible] goes up as the finger-baffle is placed, and if the finger-baffle is replaced perfectly by a [illegible] baffle the same increment of pressure takes place. We look forward [illegible] to measure cardiac output studies that will give the essential third [illegible] to this [illegible]. I have tried to present the spindle baffle operation in the most conservative [illegible] fashion. It just seems [illegible] to me to insert a [illegible] inert substance [illegible] that does not change size or shape, that does no more, and that does not propagate [illegible] as does living tissue.

I have [illegible] transbronchoscopic needle puncture of the left auricle with [illegible] of the left auricle and when possible the left ventricle. We do not have [illegible] of our catheter at the present time and cannot regard the technique as [illegible]. It does, however, seem to be reasonably safe, and we have carried it out twelve times without accident. More of these studies before and after surgery will be of [illegible]. The need for such an objective technique is as great with reference to [illegible]. Dr. O'Neill has emphasized the importance of trying to remain objective and we certainly [illegible] with this. We look forward to giving you a subsequent report.

In [illegible] it is certain that we are dealing with a far more complex disease than mitral [illegible]. The [illegible] relationships between the [illegible] valve leaflets, valve [illegible] form [illegible] a problem that will require the most careful [illegible] group over a long period. We must not become enthusiastic [illegible] have brought about improvement [illegible] [illegible].

LIGATION OF CELLOPHANE-PROTECTED ARTERIES

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INTRODUCTION

IT OCCURRED to the writer that Cellophane may be of value in tying off fragile or sclerotic vessels, especially in cases of patent ductus arteriosus. Johnson and Kirby[1] emphasized that most patent ducti can be securely closed by ligation in continuity and that recurrence is caused by failure to tie the ligatures tightly enough. They use size 0 silk and emphasize that umbilical tape or other heavy material binds upon itself, so that complete occlusion of the vessel is not at all certain. On the other hand finer type ligatures can and have cut through the ductus. In older children and adults the ductus wall may become friable and the pulmonary artery pressure elevated, increasing the risk of hemorrhage during surgery. Ligatures or clamps can cut through the vessel wall.

HISTORY

Since the original reports of ligation of a patent ductus arteriosus by Gross and Hubbard,[2, 3] Potts and associates,[4] and Touroff[5] the trend has been toward complete division rather than ligation. Nevertheless ligation is still widely used and is considered the simplest and safest procedure in many cases.

Holman and associates[6] in a series of seventy-five patients with patent ductus, treated eight by division and sixty-six by multiple ligation in continuity. There was a recurrence in one case after ligation with one ligature, and the ductus was subsequently closed with multiple ligatures. In one patient the condition recurred after triple ligation with formation of an aneurysm which was subsequently cured by division of the ductus at the site of aneurysm. One 14-year-old patient was found to have an aneurysm of the pulmonary artery opposite the entrance of the ductus. Bacterial endocarditis developed and was controlled by ligation of the ductus, wrapping of the aneurysm with Cellophane and large doses of penicillin.

Starer[7] reported fifty-one cases of patent ductus arteriosus, all of which were ligated with heavy silk without recurrence.

Possible Uses of Cellophane or Polythene in Ligation.—In simple in vitro experiments, use was made of ordinary thin nonreactive or nonirritating sheets of Cellophane such as is found as a wrapper for packages of cigarettes and other common articles. Experiments were also made with thin sheets of

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From the Veterans Administration Regional Office, Portland, Ore. The statements and conclusions published by the author are the result of his own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Photographs by Mr. Parvin M. Eaton.

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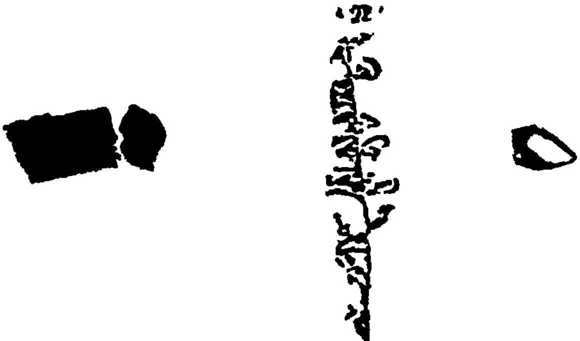
Fig. 1.—An ordinary cigarette which on the left has been clamped with a heavy Kocher [illegible]. On the right, three layers of thin Cellophane were first wrapped around the cigarette before clamping [illegible] that paper is wrinkled but cigarette is otherwise intact.

Fig. 2.—Left Figure: Left end of cigarette tied with 5-ply twisted heavy wrapping twine [illegible] cut through. Right end of cigarette first protected with three turns or layers [illegible] strip of thin Cellophane resists tearing or cutting through even with more [illegible] twine. Right Figure: A king size cigarette has been first wrapped with three layers of [illegible] strip [illegible] thin Cellophane and then tied into a knot. After the knotted cigarette [illegible] and distorted it was free of tears and intact enough to be [illegible]



nonirritating polyethylene (Polythene) such as is ordinarily used to contain and protect poultry and vegetables in the household refrigerator. The protective value of Cellophane is illustrated in Figs. 1 to 3.

Wrapping an artery such as the ductus arteriosus with Cellophane or Polythene and keeping the material closely applied to the vessel during its ligation may be a somewhat difficult procedure when working within a rather small anatomic space. Fig. 4 shows a Cellophane strip prepared and ready to be managed as described in the legend. The width of the Cellophane strip would depend on the individual case. Care should be used to avoid injuring the recurrent laryngeal nerve with the wrapping material or ligatures.

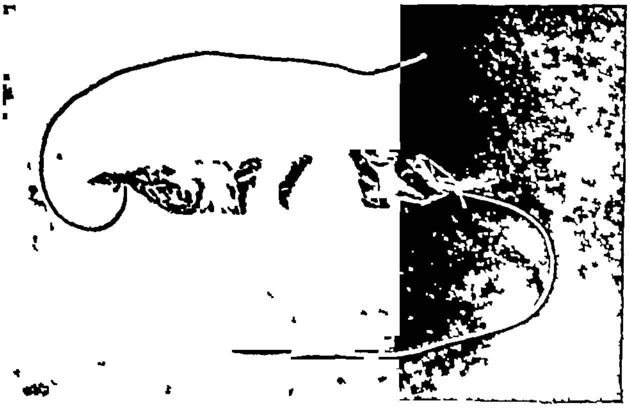


FIG. 4.—A Cellophane strip with a long piece of cotton thread tied at each end. One thread with attached Cellophane can be grasped with a fine Mixter type hemostat and pulled under the ductus. This thread is now held taut with one hand while the other thread with attached Cellophane is pulled under, over, and around the vessel two or more times as desired, each time with the aid of a hemostat. Then light traction on both threads keeps the Cellophane snugly applied to the artery so that one or more 0 silk ligatures can be applied to the Cellophane-covered artery. One central suture ligature can also be used if deemed advisable and if conditions are suitable.

It is seen (Figs. 1 to 3) that Cellophane is ruggedly resistant to tight ligature, yet is pliable enough to conform to and mold itself down to the object it is wrapped around. Although badly wrinkled, it shows no gross disruption of continuity along the line of the encircling ligature.

Polythene film is similar to Cellophane in its protective action but to a lesser degree. It is softer and more pliable than cellophane and may therefore have its field of usefulness. But when wrapped around an object, it tends to "spring out" and unroll. It is less tenacious and protective than Cellophane and ligatures tend to thin it out and cut through. It would also appear to offer less assurance than does Cellophane of preventing possible postoperative aneurysmal formation because of its more yielding nature, but may be less mechanically irritating to surrounding structures because of its softer texture.

DISCUSSION

The purpose of nonirritating (nonreactive) Cellophane or Polythene film protection described previously is different from that described in previous reports where for example Cellophane (cellulose hydrate or acetate) or polyethylene plastic film was used to wrap around arterial aneurysms, as described by Poppe[8] It appears that early samples of polyethylene contained an irritating contaminant dicetyl phosphate which stimulated connective tissue formation, it was not the Polythene per se which was responsible for reinforcing the aneurysm Since 1945 Polythene has been supplied free from this contaminant When these facts became recognized the irritating properties were deliberately utilized for connective tissue stimulation and reinforcement of aneurysms a thin layer of dicetyl phosphate powder was melted and allowed to coat over the Polythene the latter acting as a medium to hold the chemical

It is interesting to note that Donald and Kirklin[9] in experimental production of pulmonic stenosis used one or two laminated Cellophane bands 6.5 mm in width which were placed around the main pulmonary artery of dogs In some instances this produced tears in the pulmonary artery If more than one or two bands were used they combined to form a hard unyielding ring that ultimately eroded through the wall of the pulmonary artery Again it is pointed out that the purpose and method of use of Polythene or Cellophane, as described in the present article are entirely different from that of Poppe[8] or Donald and Kirklin My suggestion is that thin films of nonirritating (nonreactive) Cellophane or Polythene wrapped twice or three times around an artery, protects it considerably against the trauma of ligature or clamping Incidentally these substances may act mechanically to discourage postoperative aneurysm formation

SUMMARY

Nonirritating (nonreactive) Cellophane or Polythene film is suggested as an arterial wrapping before ligature to prevent trauma rupture or postoperative aneurysm Its possible usefulness for management of patent ductus arteriosus is discussed

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COMPLETE TRANSPOSITION OF THE AORTA AND THE PULMONARY ARTERY

AN EXPERIMENTAL STUDY OF THE SURGICAL POSSIBILITIES FOR ITS TREATMENT

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STOCKHOLM, SWEDEN

COMPLETE transposition of the aorta and the pulmonary artery is a comparatively common form of congenital cyanotic heart disease. Abbot found in an autopsy series of 1,000 cases of congenital heart disease 5 per cent of complete transposition as compared to 8 per cent of cases with tetralogy of Fallot. These children are nearly always born in a good condition but have a very short survival time. After one month one-fourth of the infants had died and after one year more than three-fourths were dead. The surgical treatment must therefore be instituted during the first months of life.

In cases with transposition of the great vessels the left ventricular output through the pulmonary artery returns to the left atrium and the blood leaving the right ventricle through the aorta returns to the right auricle. Survival of these patients depends on some type of communication between the two circulations. It has been found in cases of complete transposition that an interventricular septal defect is associated with the longest life expectancy. An interatrial septal defect is the next most favorable isolated defect, and a combination of these two gives the best prognosis of all.

Blalock and Hanlon in 1948 devised an ingenious method for the production of an interatrial septal defect under direct vision without interruption of the circulation. They tried different shunt operations on patients with complete transposition of the aorta and the pulmonary artery. The best results were obtained among the patients in whom an interauricular defect was created together with an anastomosis between the subclavian and pulmonary arteries. The patients were, however, only moderately improved and the arterial oxygen saturation generally remained below 75 per cent.

In 1953 Lillehei and Varco reported ten cases of venous transplantation in patients with complete transposition. Two patients survived the anastomosis of the right pulmonary veins to the right atrium and were improved. In four patients the inferior vena cava was shifted to the left atrium at the site of the cardiac end of the transected right pulmonary veins, the lung ends of which were anastomosed to the right atrium. None of these patients survived, a fact which was ascribed to an unbalancing of the circulation during the few minutes transpiring between the two anastomoses.

A direct switch-over anastomosis of the pulmonary artery and aorta with the aid of a heart-lung apparatus has been tried by Mustard without success.

From King Gustav V Research Institute, The Caroline Hospital (Head: Nanna Svartz, M.D., Professor) and Sabbatsberg Hospital (Surgeon in Chief: C. Crafoord, M.D., Professor).

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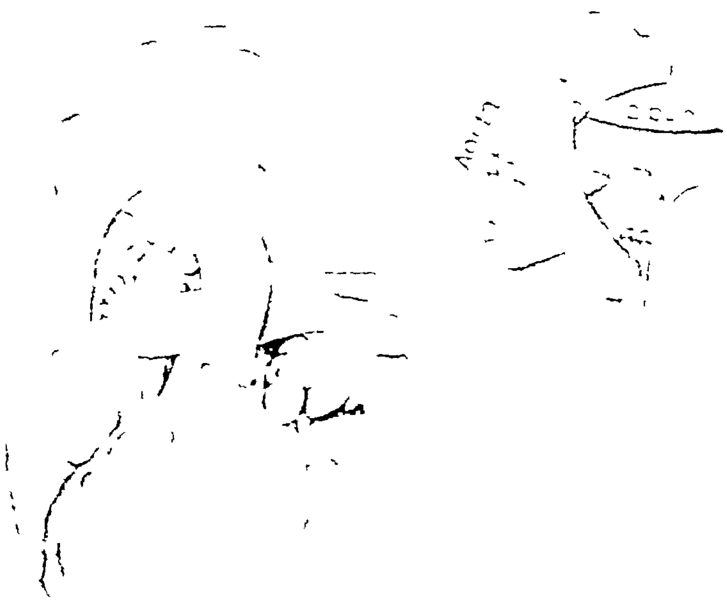
In 1954 Bailey and coworkers tried the switch-over anastomosis of aorta and the pulmonary artery under hypothermia without survival. They considered this surgical approach basically unsound since the coronary arteries nearly always arise from the right ventricular vessel.

Working with the aid of an extracorporeal circulation Gibbon has suggested that the coronary arteries have to be anastomosed as well.

ANIMAL EXPERIMENTS

As we have not had the opportunity to operate on patients with complete transposition of the great vessels, a series of animal experiments has been performed. A normal dog is less likely to tolerate any kind of cross transplantation than a patient with complete transposition.

These experiments were undertaken in order to work out a technique of switch-over anastomosis without interruption of the circulation.



[illegible]

[illegible] extracorporeal circulation or hypo[illegible] employed.

[illegible] 20 [illegible] anesthetized with Nembutal. [illegible] A subcostal [illegible] The pulmonary artery was [illegible] The [illegible] dissected free [illegible] the origin of the coronary vessels. Then the clamp designed by Beck was applied over the anterior part of the aorta as close to the coronary arteries as possible. A longitudinal side opening was made in the aorta. Then an aortic graft kept in Tyrode's solution at -4° for a maximum of two weeks was sutured into the side opening. The posterior row of the anastomosis was performed with a continuous over-and-over five-0 silk on an Atraumatic needle as recommended by Potts. The anterior row was best performed by isolated everting sutures. A continuous anterior suture on the very short part of the aortic wall inside the clamp had a tendency to cut through the brittle aortic wall. These holes were difficult to repair. The isolated everting sutures, on the other hand, can be used on a very short lip of brittle and unelastic aortic wall on old dogs without cutting through.

Fig. 2.—Photograph of a specimen from a dog with cross-transplanted grafts between the aorta and the pulmonary artery.

2. A similar anastomosis was made between the other end of the graft and the left pulmonary artery.

3. Another graft was then sutured to the main pulmonary artery as close to the right ventricle as possible.

4. The other end of the second graft was then sutured into the aorta distal to the left subclavian artery.

5. When both grafts were sutured in place it was possible to place two Potts' ductus clamps for division on the aorta and the pulmonary artery between the anastomoses to complete the switch over anastomoses. The clamps were only applied for a short time to prove the possibility of division and suture of the two ends. The clamps had to be applied obliquely to obtain

longer ends for suturing. These clamps were immediately removed and the wound sutured. The dogs survived with both grafts open for one to five hours only, when they died with pulmonary edema.

DISCUSSION

These experiments have demonstrated the feasibility of performing a switch-over anastomosis with grafts without interruption of the circulation in cases of complete transposition. All dogs died, as was expected, with pulmonary edema.

These findings will make the following conclusions obvious:

When cases with complete transposition of the great vessels are considered for surgery they must be divided in the following groups:

I. *Cases With High Pressure in the Pulmonary Artery.*—Approximately half of the cases of complete transposition are combined with an interventricular septal defect: 54 cases of 123 collected by Hanlon and Blalock, 14 cases of 29 collected by Lillehei and Varco had an interventricular septal defect as well. These cases with an interventricular septal defect and approximately the same pressure in the pulmonary artery and the aorta may be treated with a switch-over anastomosis with grafts obtained from babies who died at birth. The coronary vessels will still arise from the right ventricular vessel, but after a successful cross anastomosis the oxygen tension of the venous blood would increase considerably.

II. *Cases With a Normal Pressure in the Pulmonary Artery.*—In cases with a normal pressure in the pulmonary artery a switch-over anastomosis cannot be used. Such an anastomosis would only result in circulatory arrest due to the low pressure in the left ventricle taking over the systemic circulation, or a pulmonary edema after a few hours due to the high pressure in the right ventricle taking over the pulmonary circulation as in the dog experiments.

In cases with a normal pressure in the pulmonary artery the only treatment possible is then venous anastomosis.

SUMMARY

Cases with complete transposition of the great vessels having a high pressure in the pulmonary artery may be considered for cross anastomosis.

A technique of switch-over anastomosis with grafts without interruption of the circulation has been worked out on dogs.

Cases with complete transposition and a low pressure in the pulmonary artery cannot be considered for cross transplantation. Venous transplantation is then the only treatment.

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TUBERCULOUS INFECTIONS COMPLICATING SUBCOSTAL PLOMBAGE WITH LUCITE SPHERES FOR THE COLLAPSE THERAPY OF PULMONARY TUBERCULOSIS

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PLASTIC ball plombage thoracoplasty introduced several years ago by Lucas and Cleland,[1] and Woods, Walker, and Schmidt[2] has found acceptance among many thoracic surgeons for understandable practical and theoretical reasons. It is an operation which offers relatively good selective collapse usually without multiple stages, freedom from postoperative paradoxical thoracic motion, and little or no interference with efficient cough and the expectoration of secretions. Deformity is considerably lessened. In addition, it has been shown by Watson and Gaensler[3] that the total pulmonary function sacrificed following this plombage procedure is less than after a standard thoracoplasty of similar extent, and that the return to the final postoperative functional level is more prompt.

The presence of a foreign body for protracted periods of time in the subcostal space has caused us some concern regarding the possibility of tuberculous infection from extrapleural tuberculous foci or from the intrapleural disease by way of the lymphatics. Because of this we were led to the bacteriologic study of the fluid found in the subcostal space at the time of the operation for removal of the Lucite spheres and the rib resections performed to complete the second stage of this form of thoracoplasty. It is the results of these studies which form the basis of this communication.

During the eighteen-month period from July 1, 1952, to Dec. 31, 1953, thirty-two second stage plombage thoracoplasty procedures or "conversions," were carried out. The operations were all performed at approximately four months following the placement of the Lucite spheres. In our hands this interval, following the original operation, is optimal before the performance of the second stage. The free fluid in the subcostal space of each of these patients was examined bacteriologically by both immediate smear and culture for tubercle bacilli. Of the 32 cases converted 12 were found to have positive cultures for tuberculosis from the fluid and of these, 9 had acid-fast bacilli demonstrable by smear at the time of operation. One of this group of patients who had a positive smear and culture returned eight months after conversion with a subscapular abscess and osteomyelitis of the eighth rib. Examination of the abscess material revealed the presence of tubercle bacilli.

Lucas and Cleland[1] reported one tuberculous space infection in 125 cases six months after placement of the spheres. Meyer, De Rougemont and Labeur[4]

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found one late tuberculous infection in 20 patients at the end of four months Wada[6] states that approximately 60 per cent of subcostal spaces in which the Lucite spheres were placed became infected with tuberculosis in Japan The use of Lucite spheres in the extrapleural space was complicated by tuberculous infection in 21 5 per cent of the cases reported by Trent Moody and Hiatt In none of the above cases was there preoperative antibiotic preparation and we concede that this was in all likelihood an important factor All of our cases however had long periods of streptomycin treatment prior to surgery

The postoperative accumulation of serosanguineous fluid in the subcostal space during the first two weeks following the placement of this plomb suggested to us that although the Lucite spheres were theoretically not reactive this was not necessarily completely true

This fluid accumulation was quite variable in amount and in some patients daily tapping was required for as long as ten days after operation Woods and associates[2] also recognized this problem and examined all the aspirated fluids from their first 45 cases finding tubercle bacilli on only one occasion These early postoperative studies on the infection rate in the subcostal spaces containing the Lucite spheres have probably led to a false sense of security In our last ten patients study of this fluid revealed positive smears in one instance and positive culture in two other cases

Since the presence of the subcostal Lucite sphere plomb led to a tuberculous infection rate in more than one third of our patients this procedure should not be recommended without reservation We are cognizant of the increasing practice on the part of some clinics of leaving the Lucite spheres in the subcostal space permanently The advisability of doing this if it can be avoided requires re examination

In view of these findings we feel unwilling to permit Lucite spheres to remain in a long period of time until accumulated experience shows this to be a safe course to follow

COMMENT

Originally it was thought that the Lucite spheres would be less likely to be associated with late tuberculous infection of the collapse space than plombage materials such as oil fluids or gauze used previously On the basis of results of our bacteriologic studies we are unwilling to be more than guarded when estimating the long term outlook for these patients

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THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty fifth Annual Meeting of the American Association for Thoracic Surgery will be held April 24, 25, and 26, 1955, in Atlantic City, New Jersey Headquarters will be at the Chalfonte Haddon Hall

Requests for Hotel Reservations

These should be mailed directly to Miss Doris Sears, Convention Manager, Chalfonte Haddon Hall, Atlantic City, New Jersey Please mention this Association, the type of accommodation desired, date and approximate hour of arrival If accommodations are desired elsewhere in Atlantic City, please communicate directly with the hotel of your choice

Thoracic Surgical Forum

By vote of the membership, the Forum is to be continued for the presentation of short papers on current thoracic research, experimental problems, anatomical studies and modified or new surgical techniques The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers or to suggest their transferral to the regular program Papers at *this session will be limited sharply to ten minutes, including the showing of* lantern slides or other illustrative material At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper

These papers will be published together in one issue in the JOURNAL OF THORACIC SURGERY Maximum length 3,000 words without illustrations If illustrated, an appropriate number of words must be subtracted for each cut used

Abstracts for Papers

Abstracts for the presentation of papers at the 1955 meeting, including papers before the Forum, must be received on or before Dec 15, 1954, otherwise they will not be considered by the Program Committee

Abstracts should be labeled "For Thoracic Surgical Forum," or "For Regular Program"

Five, repeat, five copies of each abstract must be sent to the Secretary of the Association, Dr Paul C Samson, 3959 Happy Valley Road, Lafayette, California They should not be sent to the Editor

The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec 15, 1954, otherwise, the applications will be deferred for consideration until 1956

Applicants must be sponsored by three Active or Senior members of the Association In addition to the signatures on the application form, the sponsors must forward a *separate* letter concerning the applicant directly to Dr Lyman A Brewer, III, Chairman of the Membership Committee 2010 Wilshire Blvd, Los Angeles 5, Calif

Completed application forms and the sponsoring letters *independently* sent by the three sponsors must be received by Dr Brewer not later than Dec 15, 1954, to be considered for action in Atlantic City

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year

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